

**MARS: DEEP-HELD SECRETS REVEALED** p. 28

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AUGUST 2015

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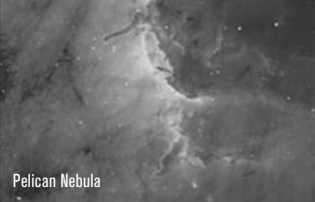


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DANA BERRY FOR ASTRONOMY

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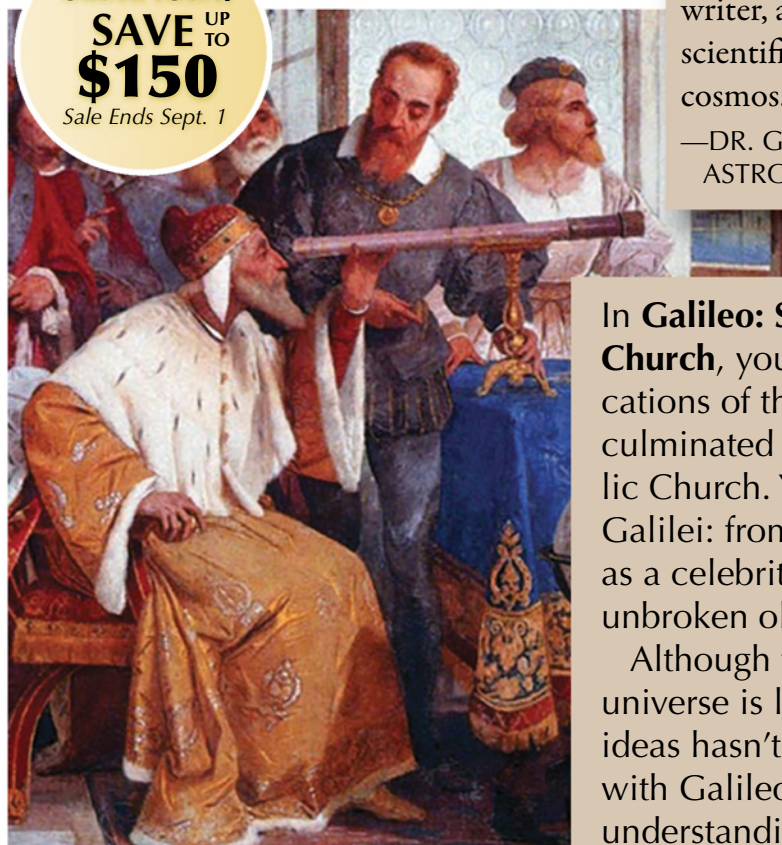
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# Join us for an eclipse in Indonesia



**T**otal solar eclipses are rare events. They are amazing, too — nothing else even remotely like them happens in nature. When the Sun fades away during daytime, animals change their behavior, the shadow of the Moon races toward you, and an almost spiritual feeling grips those watching the sky.

A spectacular eclipse will take place next March in an amazing place, Indonesia (see p. 54). I'm delighted to say that *Astronomy* magazine will be sponsoring a trip with our new travel partner, Aram Kaprielian of TravelQuest International, a company based in Prescott, Arizona. Our "Bali New Year and Total Solar Eclipse" trip will last March 2–11, 2016.

I invite you to join us for what will certainly be the

trip of a lifetime. Senior Editor Richard Talcott, an eclipse expert, will lead the group. The eclipse will take place March 9, and our tour will see it from Sulawesi, northeast of Bali, where 2 minutes and 45 seconds of totality will wash over the landscape.

Plus, many adventures will take place before and after the eclipse. The trip, featuring upscale accommodations, commences in Ubud and Batuan, where our tour group will see architectural highlights, museums, and soak in the local way of life. The days following will take us to an incredible array of places: Mount Batur volcano, the largest and most important Hindi temple in Indonesia, a seaside town with a spectacular water palace, amazing gardens, pools, sculptures,

and historic buildings.

Those who join TravelQuest will have the rare opportunity to see villagers prepare huge wooden and bamboo figures they will burn during ceremonies to celebrate Nyepi,

the Balinese New Year, which occurs on eclipse day. We'll explore temples such as Taman Ayun, the royal temple at Mengwi, as well as one of the most venerated shrines in Bali, the temple at Tanah Lot.

Still prior to eclipse day, we'll take a drive through Bedugul, exploring the magnificently terraced rice paddies covering the slopes of Mount Batukaru, a UNESCO Cultural Landscape. There will be more temples and spectacular places to see and explore before traveling to Sulawesi for the eclipse. Talcott will deliver a lecture preparing travelers with everything we need to know about eclipse day.

Following eclipse day, the group will return to Bali and enjoy the local beauty before heading back home or adding optional programs.

This will no doubt be the trip of a lifetime! Please consider joining us to bask in totality in one of the world's most exotic locales!

For a complete description of the tour, see [www.Astronomy.com/bali](http://www.Astronomy.com/bali).

Yours truly,

David J. Eicher  
Editor



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# Q&A QUANTUM GRAVITY

EVERYTHING YOU NEED TO KNOW ABOUT THE UNIVERSE THIS MONTH . . .

## HOT BYTES>>

### TRENDING TO THE TOP



#### SIBLING RIVALRY

Earth was made from the same stuff as the planet, Theia, that hit us to form the Moon, say scientists explaining why Earth and Moon rocks are so similar.



#### COLUMNS COLLAPSE

A 3-D look at the Eagle Nebula, made famous in Hubble's "Pillars of Creation" image, shows the star factory will disappear in 3 million years.



#### FIRST STARLIGHT

The first stars formed in groups 100 million years after the Big Bang, astronomers say. And just 16 such stars could outshine 100 millions Suns.



Galaxy clusters like El Gordo (ACT-CL J0102-4915) represent a small amount of the universe's mass-energy; the majority is in the mysterious form of dark energy.

## SNAPSHOT

# The mystery of dark energy

Following the explosive discovery in 1998, cosmologists still don't know what nearly 70 percent of the universe is made of.

Decades ago, astronomers thought they had a huge mystery with the discovery that so-called dark matter must exist, an unseen mass in and around galaxies. (And they did. We still don't know exactly what dark matter is.)

But in 1998, two teams of astronomers investigating supernovae made an even stranger discovery. They found evidence for an

acceleration of the universe's expansion, something they could be certain of because of the extremely well-known character of the distant stars they were observing. Suddenly, astronomers and cosmologists had an even bigger mystery: They called the repulsive force that was speeding up the universal expansion "dark energy." And no one knew why.

Recall from Albert Einstein's equations that energy and mass in the cosmos are different forms of the same thing. Thanks to the Planck satellite, we know that 68.3 percent of the mass-energy in the cosmos is in the form of this dark energy. But what is it? If you are looking for a Nobel Prize, solving this puzzle would be a surefire way to do so. — **David J. Eicher**





# STRANGEUNIVERSE

BY BOB BERMAN

## Mystery men of the Perseids

Fun facts about the most famous meteor shower.

**M**eteor showers are like nothing else in life. On what other occasion do you wait around for something sudden to happen? And why do brief dim streaks make people shout?

This month, the most famous meteors, the Perseids, unfold under ideal dark conditions, the best in five years. A hair-thin crescent Moon won't rise until morning twilight.

You know the rules. Get away from city lights to an unobstructed sky. Unlit school sports fields and hay meadows offer open sweeps of the heavens. Cemeteries are good if there aren't trees. Don't keep glancing at the people you're with. Keep your eyes glued upward. Start watching around midnight on August 12/13. You've heard all this a million times.

So let's explore a bit deeper. Start with the obvious: the best direction. Because the meteors radiate from Perseus, which rises in the northeast around 11 P.M. local daylight time, you're usually told to face that direction.

That's true early in the night when you mostly see meteors that zoom upward from the horizon. But at 1 A.M. the radiant has risen and "falling stars" streak not just upward but also to the left and right of the radiant. Fast forward to 3 A.M., and now plenty of meteors also streak downward from Perseus. There's a lot more to see, but is it still best to face northeast?

Not at all. In that direction, you only see the ones coming straight at you. Those exhibit

short streaks. If instead you face 90° from the radiant, like high in the south, you watch meteors that are zooming sideways to you. They look more dramatic because they fly across more of the sky.

Meteors are visible around 60 miles (100 kilometers) up, then disintegrate and vanish as the apple-seed-sized particles have slowed so much that they no longer heat the surrounding air to incandescence. Here's a cool fact using those same numbers: The incoming Perseid meteoroids are 60 to 100 miles (100 to 160 km) apart! Obviously, even this rich shower isn't exactly buckshot. Yet another reminder why it's called "space."

The Perseids are all debris from Comet 109P/Swift-Tuttle.

### OBVIOUSLY, EVEN THIS RICH SHOWER ISN'T EXACTLY BUCKSHOT.

Discovered during the Civil War, this comet has a 133-year orbit that brought it back around here in 1992. But who were those guys Swift and Tuttle? Were they a team like Laurel and Hardy?

Actually, Lewis Swift and Horace Tuttle were well-known American astronomers who each discovered lots of comets. Tuttle, 17 years younger than Swift, was the guy who found the parent comet of the sometimes-super Leonid shower. He also discovered the Ursid meteor shower comet.

During the Lincoln presidency, these men were the real deal, the equivalent of today's

Australian superstars Robert McNaught and Terry Lovejoy. They enjoyed long professional careers. In 1862, soon after the pair independently found the comet that would forever link their names, Swift-Tuttle grew as bright as Polaris.

No such luck during its 1992 return. Just like the Halley bust in 1986, this is not the right lifetime for earthlings to enjoy Swift-Tuttle. It had put on a darned good show in the

second century, as chronicled by Chinese astronomers. And it will again attain naked-eye brilliance next time around, in August 2126, when it passes half as close as Venus ever gets.

Comet Swift-Tuttle has a small but nonzero chance of hitting us in the far future. With its 16-mile-wide (26km) nucleus and super-fast 37-mile-per-second (60 km/s) speed, it would be far more devastating than the impact that ended the dinosaurs. Swift-Tuttle is the largest object in the known universe that makes repeated close approaches to Earth. It's the most hazardous celestial body we're aware of. Yet, thanks to their fragile

## FROM OUR INBOX

### Alien conflicts

Does anyone else find it ironic that immediately following the March 2015 p. 9 article by Editor David J. Eicher that states, "Of many thousands of UFO reports ... not one has had a shred of scientific credibility," Bob Berman writes on p. 11, "For days, the crew [of Apollo 12] watched a large, distant tumbling object out their window that kept pace with them on their way to the Moon. ... To this day, no one is sure what it was." Is that not the definition of an unidentified flying object? While we don't need to buy into radical alien theories, we do need to recognize our place in an incomprehensibly vast universe in which ancient life-forms likely flourish in an existence far beyond our ability to imagine. — **Wayne Walker**, Victoria, British Columbia

*We welcome your comments at Astronomy Letters, P. O. Box 1612, Waukesha, WI 53187; or email to [letters@astronomy.com](mailto:letters@astronomy.com). Please include your name, city, state, and country. Letters may be edited for space and clarity.*

composition, individual Perseid particles never make it to the ground. Of the 50,000 known meteorites, exactly zero are Swift-Tuttle fragments.

Jupiter can take credit for this comet's reliable clockwork period. They are linked into an 11:1 resonance. Swift-Tuttle performs one orbit around the Sun in the exact time Jupiter makes 11 circuits.

To maximally see all that juicy cometary debris, look between midnight and dawn August 12/13, when rural observers should average a meteor a minute. One night earlier offers some cloud insurance. While the sheer numbers may be 20 percent fewer during that "bonus night," the compensation on August 11/12 is a slight tendency for more bright ones and also a higher percentage with glowing trains.

So visit those friends in the country. Douse the house lights. Drag out a few lawn chairs. Share some cool Perseid factoids. And while enjoying astronomy's most famous shower, maybe salute the bearded Lewis Swift and the mustachioed Horace Tuttle. ☿

*Contact me about my strange universe by visiting <http://skymanbob.com>.*



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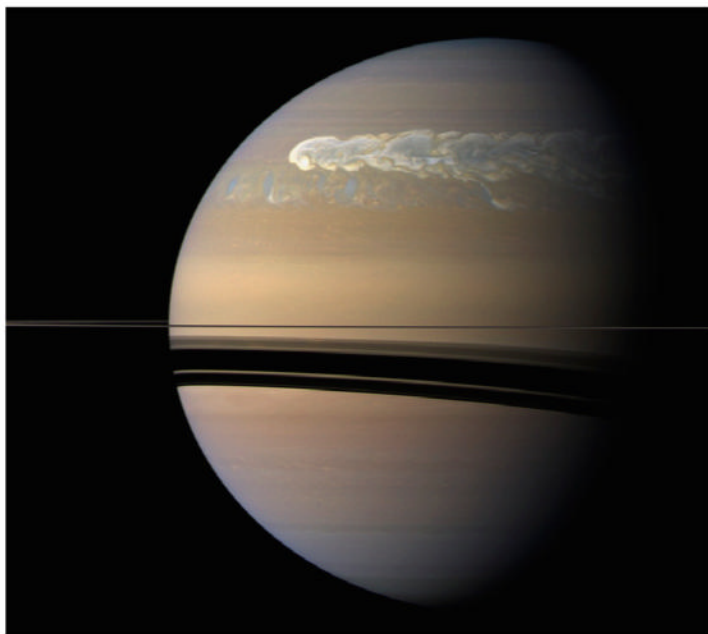
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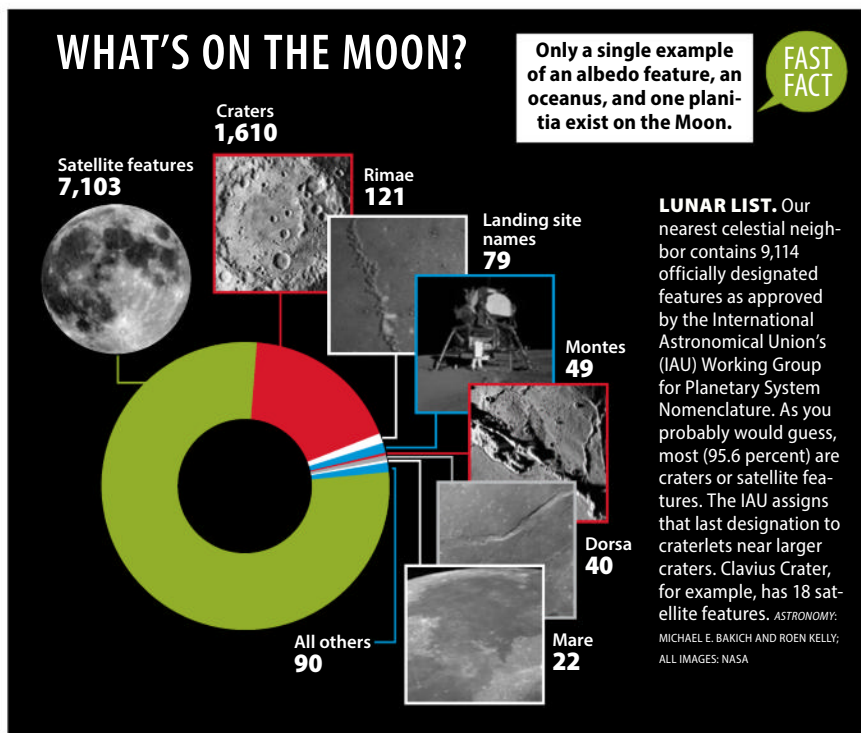
**GREAT WHITE SPOTS.** The storms seen here seem to be unique to Saturn, possibly because its gas giant sibling Jupiter lacks the necessary amount of water vapor to trigger the same kind of periodic storms. NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE

## SATURNIAN STORMS EXPLAINED

Scientists using data from NASA's Cassini mission have an explanation for the massive storms that erupt on Saturn once roughly every 30 years. The most recent event was in 2011, growing large enough to circle the planet in a bright band of white clouds.

Such monster storms rain much of the water out of the upper atmosphere, leaving

behind lighter hydrogen and helium and shutting down convection between layers. Eventually, after a few decades of isolation, the upper atmosphere cools enough that the warm, moist air underneath rises, mixing the layers again and triggering a fresh round of super-storms. Scientists described their findings in the May issue of *Nature Geoscience*. — **Korey Haynes**



## BRIEFCASE

### NANOFLARES HEAT SUN

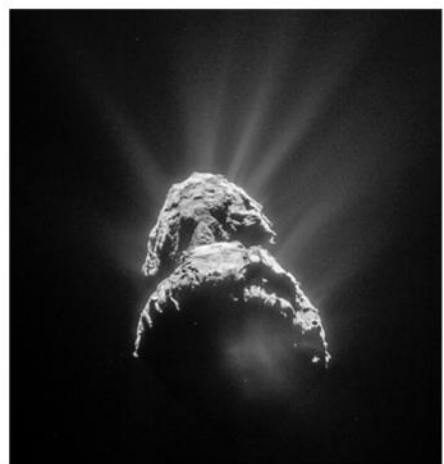
Astronomers at the first Triennial Earth-Sun Summit (TESS) meeting in Indianapolis announced April 28 that nanoflares may explain the mystery of how the Sun's corona, or outer layer, is so much hotter than its surface. Each of these nanoflares, smaller by a factor of a billion than regular solar flares, nonetheless explodes with the power of a 10-megaton hydrogen bomb and reaches 10 million kelvins (18 million degrees F). Millions of these tiny flares happen every second.

### GLASS BEADS FORM PLANETS

The solar system began as a disk of microscopic dust grains, which eventually collided and grew to form the planets. But scientists often have struggled with the details because simulated boulder-sized objects tend to fall into the Sun or destroy each other rather than joining together. Astronomers published in *Science Advances* April 17 that chondrules — tiny glassy grains that make up many asteroids — may be the solution, piling up and onto the boulders and allowing planet-sized bodies and asteroids to form.

### DARK MATTER MAYBE ONLY DIM

Dark matter is "dark" because it doesn't interact except through gravity. Astronomers published results June 1 in *Monthly Notices of the Royal Astronomical Society* that may upset this understanding. They used Hubble and the European Southern Observatory's Very Large Telescope to observe a collision of four galaxies in the cluster Abell 3827 and discovered a clump of dark matter lagging behind its galaxy. This lag is predicted if the dark matter is interacting with itself, which had not been seen before. — **K. H.**

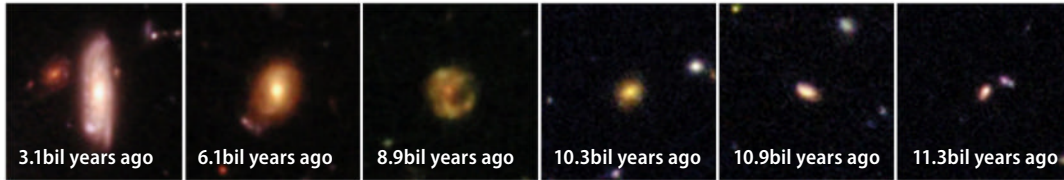


**ROSETTA'S RIDE.** Rosetta watched new jets stream off the surface of Comet 67P in late April as the icy world pushed closer to the Sun.

## Rosetta watches eruptions off a Sun-blasted comet

Comet 67P/Churyumov-Gerasimenko makes its closest approach to the Sun on August 13, reaching into a region between the orbits of Earth and Mars. The European Space Agency's Rosetta spacecraft, the first to orbit a comet, is tagging along for the close encounter, measuring the quantity and makeup of material as it spews in all directions. — **Eric Betz**





**OUR EVOLVING GALAXY.** Astronomers searched 24,000 galaxies — some billions of light-years away — for Milky Way twins to create a time-lapse of how our island universe took shape. NASA/ESA/C. PAPOVICH (TEXAS A&M)/H. FERGUSON (STSC)/S. FABER (UCSC)/L. LABBE (LEIDEN UNIVERSITY)

## Galaxy survey creates Milky Way time-lapse

Humanity's first views of Earth from space revolutionized the way we see our home planet. But humans will almost certainly never gain such an aliens' eye view from outside our galaxy. The alternative is to map what can be seen in the Milky Way and compare it to similar galaxies. Two dozen international astronomers just completed perhaps the largest such survey ever.

Their search of 24,000 galaxies picked out those that evolved like the Milky Way and also looked at how they grew over billions of years. The catalog encompasses images from three space telescopes and

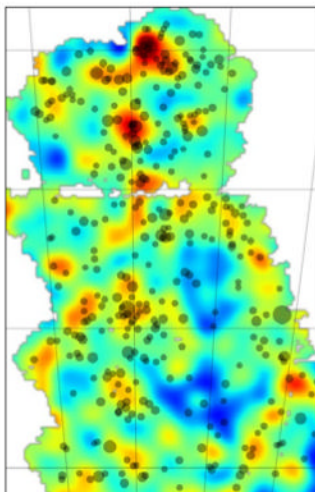
multiple ground-based instruments. This time-lapse is giving astronomers a glimpse of how our own island universe has changed since its infancy 12 billion years ago.

Our galaxy's evolution story shows a sparse collection of young stars gobbling gas from smaller neighboring galaxies until galactic puberty hit some 10 billion years ago. That's when the Milky Way began churning out new stars at a rate 30 times that of today, fueling an incredible growth spurt.

Our Sun wouldn't emerge until long after, though, taking shape some 5 billion years ago. By then, the earlier

phase of star birth and death had created the heavy elements our solar system needed for planet making.

"When we calculate the star formation rate of a Milky Way-like galaxy in the past and add up all the stars it would have produced, we find the mass growth we expected," says Texas A&M University's Casey Papovich, who was lead author on *The Astrophysical Journal* paper published April 10. "We also know that most of these stars formed inside the Milky Way, rather than in other smaller galaxies that later merged with our own. The whole picture hangs together." — E. B.



## Group makes first map of cosmic dark side

**ATLAS OF THE INVISIBLE.** The Dark Energy Survey, an international group of some 300 scientists, released its first dark matter map at an American Physical Society meeting April 13. The group used the 4-meter Blanco Telescope in Chile to produce the largest detailed map of its kind, which is only a fraction of what will be studied. By analyzing the clumpiness of dark matter, the scientists hope to quantify dark energy's role in our expanding universe. Here, mass is densest in the red and yellow regions. — E. B.



**SALTY SURPRISE.** Weather data from Curiosity's Rover Environmental Monitoring Station found conditions favorable for brine in Mars' Gale Crater. NASA/JPL-CALTECH/MSSS

## Curiosity makes the case for martian brine

The surface of Mars is cold and dry, but NASA's Curiosity rover has found clues that brine seeps in the soil at night just beneath the crust. A new study published in the May *Nature Geoscience* looks at more than one full Mars year of weather data, including temperature and humidity measurements made by the traveling lab.

The car-sized explorer recorded conditions sufficient to support small amounts of brine at the rover's position near the equator in Gale Crater. The find was possible because Curiosity is the first spacecraft to measure humidity at Mars' surface.

Scientists are chasing brine in an attempt to explain images taken with the Mars Reconnaissance Orbiter's HiRISE camera showing dark flows suddenly appearing across the planet

during warm times of the year. And a salty substance called perchlorate was already found in more northern climes by NASA's Phoenix lander several years ago. This makes scientists think salty water might cause those gullies.

By combining Curiosity's weather data with measurements of salt in the soil, scientists reason that brine could exist just beneath the surface across much of the planet.

"Conditions near the surface of present-day Mars are hardly favorable for microbial life as we know it, but the possibility for liquid brines on Mars has wider implications for habitability and geological water-related processes," says lead study author and Curiosity science team member Javier Martin-Torres of the Spanish Research Council. — E. B.

## QUICK TAKES

### ROCKY PAST

Scientists unraveled Earth's layered history thanks to a piece of the asteroid Vesta. By comparing rare meteorite minerals to Earth's oldest rocks, they showed our crust formed over 4.5 billion years ago.

### FARAWAY WORLD

NASA's Spitzer Space Telescope paired with ground-based instruments to find a gaseous planet 13,000 light-years away in our galaxy's bulge. It's among the most distant known.

### NO PLACE LIKE HOME

Detectable life is unlikely at two exoplanets around nearby star Tau Ceti. A new look shows life-friendly orbits emerged recently and that their rocks might cause strange volcanism and tectonics.

### GIANT SPECS

The Large Binocular Telescope showed its might by imaging an erupting lava lake on Jupiter's volcano moon Io. The instrument pairs 8.4-meter mirrors into the equivalent resolution of a 22.8-meter telescope.

### ROBOSCOPE FIND

Lick Observatory's Automated Planet Finder turned up two new super-Earths — planets seven to eight times bigger than ours — in the already known solar system of nearby star HD 7925.

### COSMIC FLOOD

Water couldn't form until the first stars made oxygen and it combined with hydrogen. But new models show warm temps might have made water abundant in the first billion years after the Big Bang.

### NOT-SO-BLACK HOLES

Information lost into a black hole might (theoretically) be recovered thanks to the way particles interact inside, say University of Buffalo physicists chasing a problem Stephen Hawking first posed some 40 years ago.

### 67P NOT MAGNETIZED

ESA's Rosetta and Philae spacecraft paired to search for signs of magnetism at Comet 67P, but found none. The find casts doubt on a theory that magnetism played a role in accumulating these planetary building blocks. — E. B.



# A false dichotomy

Is there in truth no beauty?

In 2001, a group of scholars packed into an auditorium at New York University to hear English artist David Hockney present his theory that since the Renaissance, many painters have used optics in their work. The photorealistic paintings of Dutch master Johannes Vermeer were among Hockney's examples. To Hockney and his collaborator, optical scientist Charles Falco, Vermeer's paintings bear the unmistakable signature of camera-like projection.

But many in the room had come not to praise Hockney for his insight, but to convict him of heresy. They were offended at the suggestion that the ineffable genius of revered artists might have benefited from anything so vulgar as lenses and mirrors. One museum curator insisted that Vermeer's attitude had been, "To hell with physics!" Characteristically witty, writer and critic Susan Sontag likened the reliance of art on optics to the reliance of sex on Viagra.

The battle lines that day were drawn between what C. P. Snow called "The Two Cultures." On one side are art and the humanities, expressions of the human spirit; on the other side is science, the haven of cold, dehumanizing rationality. "The Two Cultures" are stamped indelibly onto the zeitgeist of our times.

Personally, I don't get it.

Listen to conversations among scientists, and you might be surprised to catch phrases like "playing with the data," the "beauty of an experiment," or the "elegance of a theory." You might hear passion about intuition or the aesthetic that guides their work.

Trade lab coats for fedoras, equations for lead sheets, and scientific jargon for the esoteric

language of jazz, and you might confuse the scene with a bunch of musicians taking five during a recording session! The distinction might blur further if the discussion turned to the technical side of making and recording musical sound.

In both cases, you would be witnessing the same thing: human creativity at work.

The notion of a gulf between science and art would have puzzled Leonardo da Vinci. He and others moved beyond received wisdom — and invented modern science — precisely by applying an artist's creativity and careful eye to questions of how the world works.

All of which raises the question: If science and art are so similar — both human expressions of the creative drive to experience and comprehend the world — then why are they viewed so differently?

The answer lies in the jury process. Art finds its value in the subjective response of its audience. In contrast, many a beautiful scientific theory has been abandoned for the simple crime of making predictions that were incorrect.

Science can be uncomfortable because it says, "What you want doesn't matter." You might want astrology to work. You might want global warming to be a hoax. You can stomp your foot as much as you like and even get yourself elected to Congress. But that still doesn't make it so. Some people have trouble accepting that.

Inventor and technologist Tim Jenison had a lot to do with bringing computer animation to the world — two Emmys' worth. Turning revolutionary technology into revolutionary art is his



Johannes Vermeer captured the light and details of *The Music Lesson* so perfectly that some wonder if he used optical aid. If he did, would that make him an art fraud or simply a different kind of genius? THE ROYAL COLLECTION, HER MAJESTY QUEEN ELIZABETH II

life's work. When Jenison heard about Hockney's ideas, he was intrigued. But instead of opinion, Jenison saw Hockney's work as a scientific theory to be tested. So he set out to do just that.

Jenison's early experiments with a mirror on a stick grew into an obsession. After years mastering everything from polishing lenses to making his own paint, all using 17th-century techniques, it was time for his grand experiment. He would attempt to paint his own version of Vermeer's masterpiece, *The Music Lesson*.

Day after day, month after month, Jenison devoted himself to the demanding and tedious work. One brush stroke at a time, he used his optical device to meticulously match pigments on canvas to light from the scene. When finished, Jenison's painting was undeniably beautiful. It also perfectly captured the precise perspective and illumination that define Vermeer's style.

Jenison's remarkable story is chronicled in the delightful documentary film *Tim's Vermeer*. Narrated by Penn Jillette and directed by his partner, Teller,

*Tim's Vermeer* has received widespread critical praise.

But many in the art history community are no happier with the idea now than they were in 2001. Jonathan Jones, writing for the *Guardian*, pulled no punches in his scathing critique. "At last," wrote Jones, "an art film for philistines."

Did Jenison prove that Vermeer invented and used a forerunner of modern copy cameras? No. But Jenison *did* successfully demonstrate an optical method that would have allowed Vermeer to produce the unique works of art that continue to marvel us to this day.

Immersed in the scientific and artistic excitement of the Dutch Golden Age, if Vermeer did invent such a powerful technique, why *wouldn't* he have used it?

I enjoyed *Tim's Vermeer*. At last, a film about science and art for those who insist they are two sides of the same coin. ♣

Jeff Hester is a keynote speaker, coach, and astrophysicist. Follow his thoughts at [jeff-hester.com](http://jeff-hester.com).



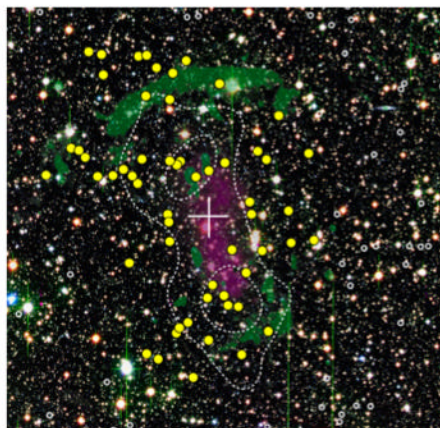


**ASTRONews** **RED DUSK.** The malfunctioning Russian resupply ship Progress 59 plummeted to Earth on May 8 with 3 tons of undelivered space station supplies.

## Studying the largest structures in the cosmos

When two galaxies collide, they stir up vast clouds of gas, triggering explosive bouts of star formation and lighting up with young blue stars, in contrast to the older red populations that fill quiescent galaxies. But when clusters of thousands of galaxies collide, astronomers thought that not much would happen. The space between individual galaxies, even in clusters, is so vast that it wasn't clear that the impact — which does release a giant shock wave — would be felt on the comparatively tiny scale of star-forming regions. But in a study published in the June 11 *Monthly Notices of the Royal Astronomical Society*, astronomers announced that they see previously "dead" galaxies in the merging cluster CIZA J2242.8+5301 (helpfully nicknamed the Sausage) flaring up again with newborn stars. The revival will be short-lived, so catching the Sausage during its active state was a stroke of luck.

A separate group of scientists are looking even further back in time to see how clusters formed in the early universe. They used the European Space Agency's Herschel and Planck space observatories to peer back to only 3 billion years after the Big Bang, where they found bright sources densely clustered and churning out new stars. The astronomers believe these could be the precursors of the mature galaxy



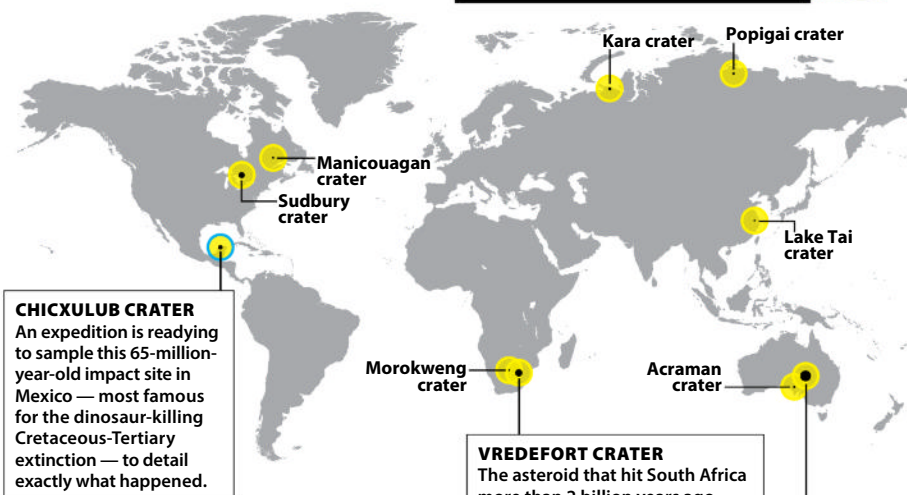
**BUILD IT BIGGER.** The merging Sausage Cluster is one of the most massive in the universe. In this image, yellow dots represent galaxies that are part of the cluster, purple marks hot gas between the clusters, and green indicates where the shock waves are measured. The contours roughly trace out the two clusters as they merge. ANDRA STROE

clusters they see in the modern universe. They published their results online March 31 in *Astronomy & Astrophysics*. — K. H.

## WHEN DISASTER STRIKES

**Asteroid impacts can alter history, yet few of Earth's 10 largest craters are conclusively tied to an extinction.**

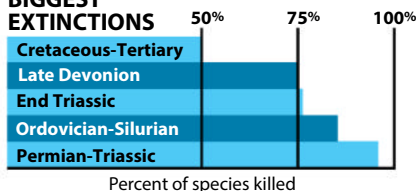
FAST FACT



### CHICXULUB CRATER

An expedition is readying to sample this 65-million-year-old impact site in Mexico — most famous for the dinosaur-killing Cretaceous-Tertiary extinction — to detail exactly what happened.

### BIGGEST EXTINCTIONS



Percent of species killed

### VREDEFORT CRATER

The asteroid that hit South Africa more than 2 billion years ago made a crater nearly 200 miles (320km) across. The oldest known Earth impact site has since eroded, leaving strange rings.

### WARBURTON CRATER

In 2009, a geologist drilling for geothermal energy noticed strange quartz grains similar to ones seen at a far-off Australian impact site, prompting colleagues to chase conclusive evidence.

**CURTAIN CALL.** Australian geologists recently announced they'd found the largest impact site on Earth — twin craters a whopping 280 miles (450 kilometers) across in Warburton Basin. The asteroid chunks must have hit more than 300 million years ago, as granite layers show shock from the impact while overlying material doesn't. But other rocks indicate a 420-million-year-old impact. Once scientists can nail down the date, they can start searching for evidence of the devastation unleashed, including a likely extinction event. *ASTRONOMY: ERIC BETZ AND ROEN KELLY*

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# WHAT ARE CERES' WHITE SPOTS?

Like Pluto, astronomers once called Ceres a planet. But unlike Pluto, which lurks on the ragged edge of the solar system, Ceres is Earth's comparative neighbor. Its orbit sits just beyond Mars in the inner asteroid belt, where, like Pluto, it is the largest known object. And yet no earthling had glimpsed Ceres' surface until this year.

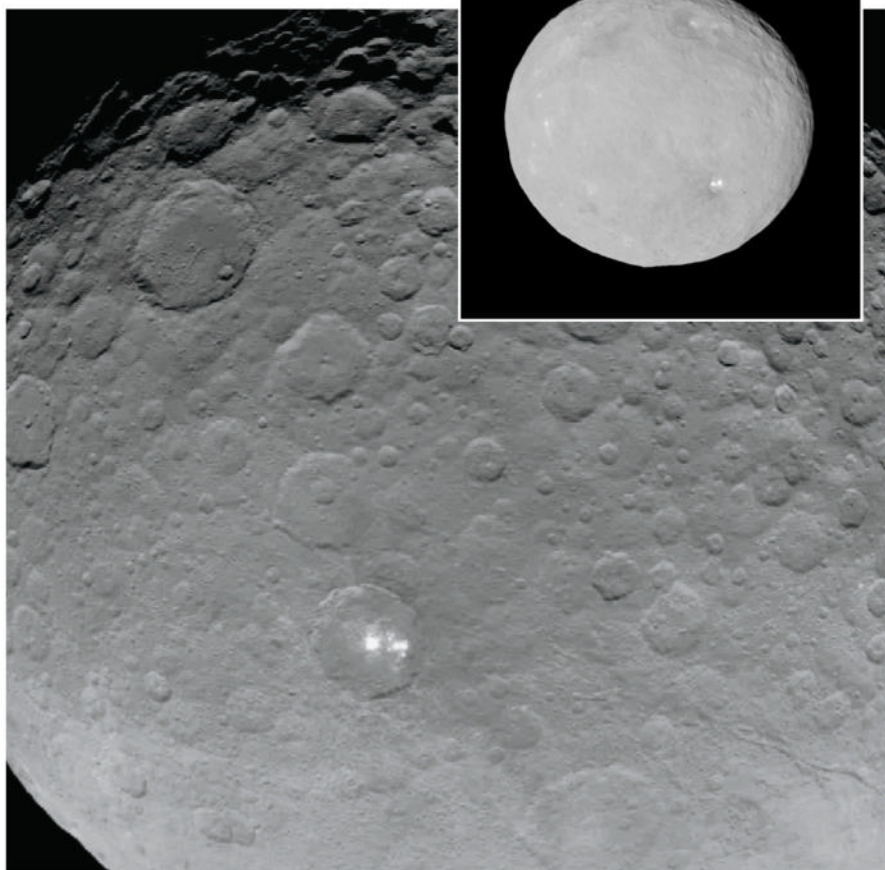
So, as NASA's Dawn spacecraft arrived in March, two bright white spots in one of the dwarf planet's craters caught astronomers' attention. The European Space Agency's Herschel space telescope saw signs of water plumes at Ceres last year, but Dawn has yet to see any evidence of such icy volcanism.

Then, when the spacecraft descended toward its science phase orbit around 4,500 miles (7,200 kilometers) above Ceres in May, the white spots resolved into a colony of smaller splotches.

What are they?

"Dawn scientists can now conclude that the intense brightness of these spots is due to the reflection of sunlight by highly reflective material on the surface, possibly ice," says Principal Investigator Christopher Russell of the University of California, Los Angeles.

But the craft must get closer to find out for sure. In August, Dawn begins mapping Ceres from an altitude of 900 miles (1,450km) before navigating in even closer later this year. — E. B.



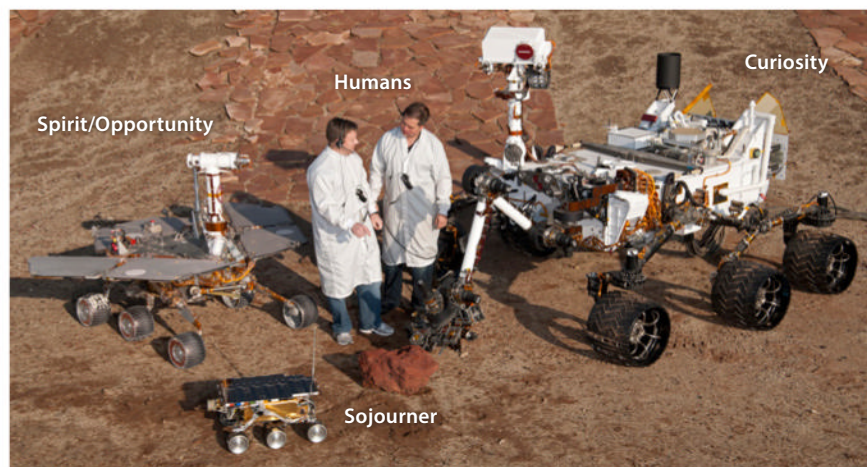
**SPLOTCHY THING.** The first views from Ceres show a dwarf planet covered in large craters as well as smaller secondary craters formed by impact debris crashing back down to the surface. Long linear features that look like scarps could indicate some form of tectonic forces at work. But the most fascinating find to mission scientists remains the odd white spots that have been prominent since NASA's Dawn spacecraft was still far off from the solar system's largest asteroid. The coming months should reveal their true nature. NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA

**25%** Amount of the asteroid belt's total mass contained in dwarf planet Ceres. Despite this seeming bulk, far-off Pluto is some 14 times bigger.

## SIZING UP THE MARS ROVERS

Curiosity weighs a whopping 1,982 pounds (899 kilograms), compared to Sojourner's slim 25 pounds (12kg).

FAST FACT



**ROBOT EVOLUTION.** From the Pathfinder mission's Sojourner to Mars Science Laboratory's Curiosity, martian rovers have gotten both bigger and better with time. NASA/JPL-CALTECH



### 25 years ago in Astronomy

In August 1990, Stephen Cole overviewed the many tests the newly launched Hubble Space Telescope was running before science collection could begin. The mirror deformation that nearly ended Hubble's science life before it began was yet to be discovered.



### 10 years ago in Astronomy

In the August 2005 issue of *Astronomy*, Michael Carroll described the Mars Exploration Rovers Spirit and Opportunity's first year of results. While Spirit is now mired and unresponsive, Opportunity is roving and exploring to this day. — K. H.



# ASTRONWS



**STELLAR CORONER'S REPORT.** Astronomers think galaxies grow from blue star-forming disks into spheroids, with star formation shutting down first in the center (shown in red) and then spreading out to the galaxy's edges. ESO

## Galaxies die from inside out

New research published April 17 in *Science* explains how the most massive galaxies in the universe evolve. Elliptical galaxies are both enormous and old, with the bulk of their star formation having shut down about 10 billion years ago, leaving only small, long-lived red stars still burning. Scientists often refer to these galaxies as "red and dead."

Astronomers used the Hubble Space Telescope and the European Space Agency's Very Large Telescope to view the spatial distribution of stars in 22 of these galaxies and found that the youngest stars appear around the edges, indicating that star formation shuts off first near the galactic core. — K. H.

# 228,276,482

The number of stars in the United States Naval Observatory's new catalog




ALMA (NRAO/ESO/NAOJ); B. SAXTON (NRAO/JNPF); NASA/ESA/HUBBLE; T. HUNTER (NRAO)

## ALMA spies Einstein ring

**RING OF FIRE.** Astronomers with the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile spotted a faraway (12 billion light-years) galaxy via a rare cosmic alignment known as gravitational lensing. A massive galaxy (the diffuse blue light) passed in front of a more distant galaxy and bent the background object's light around it to form a nearly perfect circle of repeating images, known as an "Einstein ring." The scientists were testing ALMA's highest resolution capabilities and will publish their results in *The Astrophysical Journal Letters*. — K. H.

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## OBSERVING BASICS

BY GLENN CHAPLE

# Here comes the Sun

Double your observing time by adding some daylight hours.

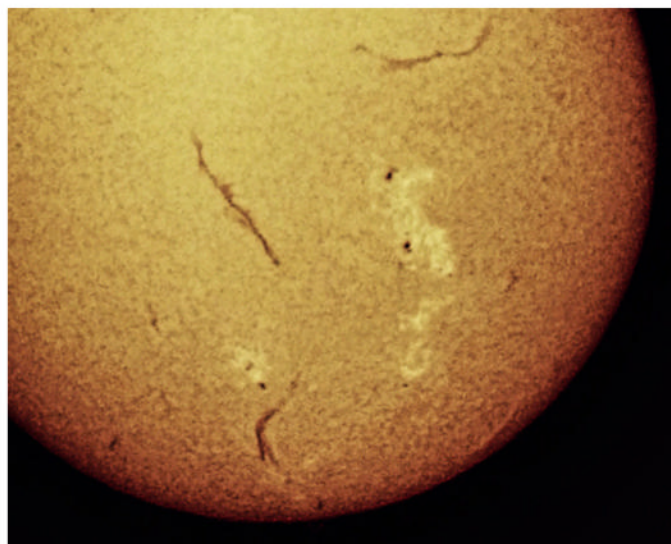
**F**or amateur astronomers who hunt at night for deep-sky prey, the Sun is a nuisance. Sunrise allows nebulae, clusters, and galaxies to go into hiding, forcing these night owls to give up the chase. It's their loss because the Sun is arguably the ultimate in cosmic big game. There is a real element of danger to this daytime hunt. Veteran Sun-stalkers know that, like the game animals that inhabit plain, forest, and jungle, the Sun can strike down the unwary pursuer — not with fang and claw, but with a blinding flash of light.

The time-honored way to view the Sun in relative safety is by using the telescope to project a solar image onto a white cardboard sheet. Not only is the method safe, but it's also simple and inexpensive. The Sun's overwhelming light and heat mandate a minimal amount of aperture; large scopes should be downsized with a 2- to 3-inch-diameter aperture mask. Even then, enough heat can accumulate to "cook" an expensive multi-element eyepiece. Opt for something simple and inexpensive (the Huygens or Ramsden

designs are ideal), and make sure it's low power. The entire solar disk and relevant detail can be captured with magnifications of just 20–30x.

When aiming a telescope toward the Sun, *never* use the finder! Keep it covered, especially if you're hosting a solar star party where a curious attendee might try to sneak a peek (it happened to me!). Instead, rely on the shadow of your scope's tube. When it's as compact as can be and the eyepiece is brightly illuminated, you're on target. Position the cardboard sheet about a foot from the eyepiece, and focus until the bright circle of light (the Sun's projected image) is sharp at the edges.

This circle is the Sun's photosphere, or visible surface. If there is any solar activity, you should see sunspots — gray blotches with dark centers. Dark only because they're cooler than the surrounding surface, sunspots change appearance from hour to hour and day to day as they evolve and drift in and out of view with the Sun's rotation. Higher magnifications allow a detailed look at the photosphere, revealing its mottled,



Observing and imaging the Sun (even using a smartphone, as done here) with a safe solar filter will reveal stunning features. TED HAUTER

grainy appearance. This is granulation, an effect produced by masses of hot gas rising, cooling, and then sinking on the Sun's seething surface.

Since high magnification isn't necessary for casual solar observing, will binoculars suffice? I'd say yes, but I worry about the risk to the optics should binoculars be used for solar projection. If you'd like to observe the Sun with binoculars or simply prefer a direct telescopic view, invest in an aperture solar filter. Made of black polymer, Mylar, or specially coated glass, it affixes to the front of the binocular barrel or telescope, blocking out all but a safe amount of incoming light. Costs depend on type and telescope aperture, ranging from \$20 for a black polymer filter suitable for standard binoculars or a 2-inch refractor to over \$200 for a glass filter designed for a 16-inch scope. Do-it-yourselfers who wish to construct an aperture solar filter should look into a tutorial posted on the website of the Springfield Telescope Makers. Log on to <http://tiny.cc/stellafanesun>.

Small-aperture telescopes manufactured during the latter half of the 1900s were often accessorized with Sun filters that screw into the eyepiece. Don't use them! Concentrated heat at the eyepiece has caused

screw-in Sun filters to shatter without warning. Don't believe me? My January 2010 column, "Screw-in solar filter hazards," relates several accounts from readers who were momentarily blinded when theirs suddenly splintered.

Solar projection and aperture Sun filters deliver what is called a "white light" view of the Sun. If you'd like to see our star in a whole new light (literally!), look into a specialized filter or telescope that allows only a narrow bandwidth of light (in this case, the Hydrogen-alpha line of the solar spectrum) to reach the eyepiece. They're a lot more money — a few hundred dollars to as much as a few thousand — but the visual reward is worth every penny. What could be more breathtaking than to view a solar prominence arching high above the Sun's limb or to capture a solar flare erupting from the vicinity of a sunspot?

If you're a dedicated backyard astronomer, don't limit your quest to the denizens of the night sky. The most magnificent prey of all roams the daytime sky.

Questions, comments, or suggestions? Email me at [gchaple@hotmail.com](mailto:gchaple@hotmail.com). Next month: We see the unseen! Clear skies! ☽

## FROM OUR INBOX

### Beyond description

I have read with pleasure your magazine for years! I just had to send a note to tell you that the recent issues have been outstanding, and I devour each one every month. However, your issue with "500 coolest things" (March 2015) was beyond description. I read every page, anxiously waiting to turn the page to reveal the next coolest thing. I am halfway through rereading them. Thank you! — **Steve Umland**, Stone Lake, Wisconsin



BROWSE THE "OBSERVING BASICS" ARCHIVE AT [www.Astronomy.com/Chaple](http://www.Astronomy.com/Chaple).



## HOW WILL THE NEW HORIZONS TEAM GATHER DATA FROM THE PLUTO FLYBY?

With the New Horizons mission, we've taken the mass-production approach to gathering data on the Pluto system. We're going to collect so much information that we won't get it all back to Earth until late 2016. So even though the spacecraft will be long past Pluto, there will be data sets on New Horizons with discoveries just waiting to happen for 16 months and analysis of the data beyond that.

The mission has an adaptable process regarding the order in which the info comes back. We've established with NASA a basic priority list, what we call Group 1 science — the most important — Group 2, and Group 3. Group 1 consists of composition maps, geology maps, and atmospheric data. Group 2 includes searching for an atmosphere around Pluto's large moon Charon, thermal maps, stereo maps, and more. And Group 3 has things like searching for magnetic fields, hunting for new moons, and refining the masses and orbits of the known satellites.

We're basically going to send all the Group 1 data home before we start with Group 2, and then all of Group 2 before Group 3. And then within that, we'll take turns among our different theme teams — atmospheres, geology and geophysics, and composition. Every month as we're planning our downlink, the team leaders will meet with me as the principal investigator to propose certain atmosphere data sets, geology data sets, and composition data sets from Group 1. We'll make sure they fit within the amount we can send home in the month, and then we'll check them off the list. Once Group 1 is done, we'll move on to Group 2, and so on. By doing things in this priority order, it's a little insurance against the very unlikely event the spacecraft goes haywire during the downlink year. And for the public, with fresh data sets coming to the ground all the time, it will seem like we're spending more than a year with Pluto.

### S. Alan Stern

Principal investigator of the New Horizons mission, Southwest Research Institute, Boulder, Colorado

New Horizons' images will improve on the best Hubble images of Pluto by a factor of 5,000 by the time it arrives July 14.

FAST FACT



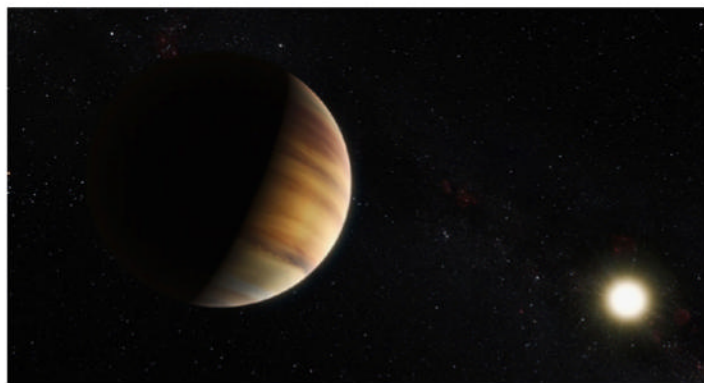
New Horizons' enhanced view of Pluto from 46.6 million miles (75 million km) away

RAYNA TEDFORD (PORTRAIT); NASA/JHU/PSRI (PLUTO)

## ASTRONOMY

**COSMIC COLD SPOT.** The universe's largest known structure — a cold spot 3 billion light-years away — is likely a supervoid, a vast area with few galaxies that slows and stretches light moving through, making it look cold.

## First exoplanet makes fresh news



**FROM MYTH TO REALITY.** 51 Pegasi b, popularly called Bellerophon, allowed astronomers to say definitively for the first time that planets exist around other stars like the Sun.  
ESO/M. KORNMESSER/NICK RISINGER

Astronomers from the European Southern Observatory's La Silla Observatory in Chile have observed the first visible-light reflection spectrum of an exoplanet on 51 Pegasi b. Usually when astronomers study the spectrum, or chemical fingerprint, of an exoplanet, they must study the star's light that passes through the planet's atmosphere when the planet transits, or crosses between the observer and the star. But not all planets align to afford this kind of view, so the excitement of the new method, published online in *Astronomy & Astrophysics* April 22, is that it can deliver a spectrum without requiring a transit.

Astronomers are searching for the planet's reflection of the star's light. So they carefully examine the star's spectrum and then look for

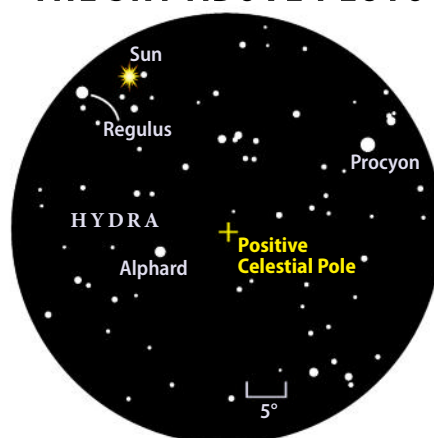
a similar but scaled-down signature in the light they receive from the system. This tiny echo can be easily lost in the glare of the star and signal noise but should be even more accessible with upcoming instruments on the Very Large Telescope.

It is especially fitting for the new method to be used on this particular exoplanet system. In 1995, 51 Pegasi b became the first exoplanet discovered around a main sequence, or normal, star. It was also the first known hot Jupiter, a highly irradiated gas world that has no analog in our solar system. Twenty years on, astronomers have discovered nearly 2,000 exoplanets and dozens of hot Jupiters, but 51 Pegasi b is still making waves. — K. H.

The brightest star in the field during mid-August is the Sun — a dazzling point of light shining at magnitude -19.

FAST FACT

## THE SKY ABOVE PLUTO



**REPTILIAN POLE.** These are the stars you would see if you looked overhead from Pluto's positive pole August 15. (When the International Astronomical Union demoted Pluto to dwarf planet status in 2006, the definitions of the world's two poles got reversed; the so-called positive pole now points south of the solar system's plane.) The distant planet's axis points toward a spot in the constellation Hydra the Water Snake some 9° from the 2nd-magnitude star Alphard. ASTRONOMY: RICHARD TALCOTT AND ROEN KELLY



# SECRETSKY

BY STEPHEN JAMES O'MEARA

# The "Aristarchus X"

Locate this unfamiliar feature on the Moon's surface.

Whenever I want to refresh my lunar observing, to see the Moon in new and uncommon ways, I wait for its phase to wane and point my telescope to the lunar terminator — that bleak and shadowy domain that separates lunar day from night. Then I sweep its full length. My eye usually searches for things dramatic — shadowy rough-and-tumble landscapes whose ragged relief cries out for attention.

But on the morning of March 14, 2015, a subtle sighting in Oceanus Procellarum (Ocean of Storms) on the Aristarchus Plateau (then situated midway between the terminator and the limb) immediately put me off my routine and gave me pause for thought.

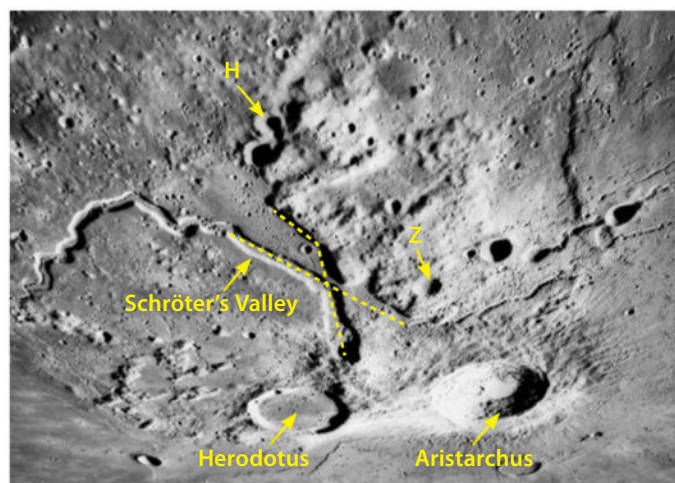
## Plateau superlatives

That the Aristarchus region would capture my interest is

not by any means surprising. Among its many superlative characteristics, the plateau is home to Aristarchus, a young impact crater 25 miles (40 kilometers) across and twice as deep as the Grand Canyon. Aristarchus has a "comet tail" of ejecta so reflective that it is one of the brightest features on the Moon and easily visible to the unaided eye.

The Aristarchus Plateau also hosts the densest concentration of lunar sinuous rilles (ancient lava channels) and the largest deposit of pyroclastic debris ejected during rare bouts of explosive volcanism. Schröter's Valley, the largest on the Moon, snakes away from the northern midpoint between Aristarchus Crater and the similarly sized (but lava-flooded) crater Herodotus.

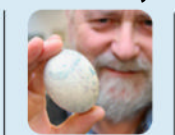
Schröter's Valley meanders northwestward for 87 miles (140km). Its cobra head is believed to be the source of the tremendous outflowing of lava



This image of the Aristarchus Plateau and its craters clearly shows the feature the author calls the Aristarchus X. NASA

## COSMIC WORLD

A look at the best and the worst that astronomy and space science have to offer. by Eric Betz

Cold as space			Supernova hot
<b>Run, Oppy! Run!</b>	<b>Real World: Mars</b>	<b>Archival embryo</b>	<b>End of solitude</b>
			
JPL scientists run to mark the Opportunity rover's 11-year, 26.2-mile (42.2km) Mars marathon. Despite good health, the plucky rover may be at the finish line. NASA plans to end funding in 2016.	Space settlers with a Mars death wish seem even less likely to have that chance after news stories show Mars One's plans for a Red Planet reality show are as real as any earthly reality show.	The Library of Congress asks for an egg that Phil Stooke used in 1977 to map Phobos and its strange valleys. It'll appear next to the rubber ducky European scientists are using to understand Comet 67P.	NASA Chief Scientist Ellen Stofan says alien life exists and humans will find it by 2025, with definitive proof to follow. If right, most of us will see extraterrestrial microbes in our lives.

NASA/JPL/CORNELL UNIVERSITY (RUN, OPPY! RUN!); NASA/JPL-CALTECH (THE REAL WORLD: MARS); PAUL MAYNE/WESTERN NEWS (ARCHIVAL EMBRYO); ESA/RALPH O. SCHILL (END OF SOLITUDE)

## FROM OUR INBOX

### A simple thanks

My message is simply this. Yours is an extremely well done and fun to read magazine. Here's why: Learning is exciting. And your magazine always brings us to the edge of what is now known. It makes us feel like children looking up into the vastness of outer space and wondering. You help us by keeping all the important questions fresh and open. And so, thanks.

— Paul Theriault, Ridgeway, Ontario

that crossed the plateau and formed the rille. Now add the ever-changing lighting effects caused by the Sun at various altitudes to this varied and chaotic terrain. When you do, it becomes a virtual playground for all manner of visual effects that can manifest and dissolve over time to create temporal telescopic wonders.

### X marks the spot

It was one such curious effect of sunlight reflecting off the walls of Schröter's Valley and some neighboring cliffs that captured my attention. The light segments together created a striking white "X" (oriented roughly northwest-southeast) that teased my mind's eye. I was using only a 3-inch refractor, yet I clearly detected the individual surface

details constituting the X's three components: The curved sunlit eastern rim of Schröter's Valley forms one side of the X, while sunlight reflecting off two slightly angled cliff faces in deep ejecta blankets — one south of the crater Herodotus H, the other southwest of Aristarchus Z — creates the individual arms of the X's other side. The pale glint off the lower cliff face near Aristarchus Z was the most subtle detail at the time of my viewing (5h UT), and defining it required moments of steady seeing — the utmost demand for any probing look at lunar or planetary features.

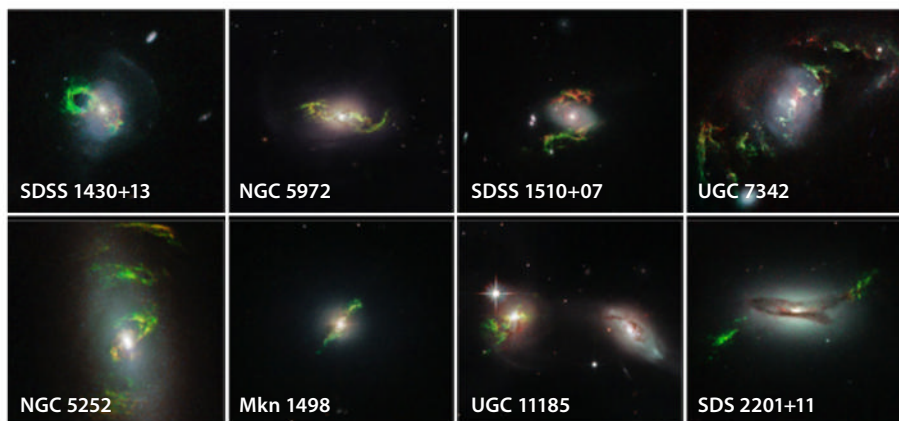
If you've seen this X-shaped feature or make observations of it, send them to sjomeara31@gmail.com; I'd love to hear about what you see. ☾



BROWSE THE "SECRET SKY" ARCHIVE AT [www.Astronomy.com/OMeara](http://www.Astronomy.com/OMeara).



**STUFF OF LIFE.** For the first time, astronomers detected complex organic molecules — the building blocks of life — in a still-forming star disk.



JASA/ECA/W KEEI (UNIVERSITY OF ALABAMA TUSCALOOSA)

**GREEN GOBLINS.** The Hubble Space Telescope has imaged eight more green objects similar to Hanny's Voorwerp, discovered in 2007. They represent the light echoes of once active supermassive black holes.

## Uncovering the echoes of active galaxies

In 2007, Dutch schoolteacher and citizen scientist Hanny van Arkel was thrust into the astronomical spotlight when she uncovered a strange green object in a Sloan Digital Sky Survey image she was studying as part of the Galaxy Zoo project. Follow-up studies of the bizarre find, dubbed Hanny's Voorwerp (Dutch for Hanny's object), so intrigued the University of Alabama's William Keel that he began a new citizen science project to find similar green structures near other galaxies. The results, published in the May issue of *The Astronomical Journal*, show that objects like Hanny's Voorwerp are the echoes of once active galaxies.

Keel's search uncovered 20 more examples like Hanny's Voorwerp, except each has its own unique shape. They exist far from their host

galaxies' centers and are thousands of light-years long. Astronomers believe they are gas filaments illuminated by long-ago bursts from the regions around active supermassive black holes, called quasars, through photoionization; oxygen, helium, nitrogen, sulfur, and neon absorb light from the quasar and slowly re-emit it over time, with the ionized oxygen providing the green hue. Because the filament lies on the outskirts of the host galaxy, the activity from the quasar took tens of thousands of years to light up the green structure, explaining why these objects are visible when the quasars are no longer bright. Keel's study supports the theory that the gas filaments resulted from a previous galaxy merger; such an event also could have ignited the quasar for a time. — **Karri Feron**

**6 million mph**  
(3,000 km/s) The average escape speed required for a galaxy to break free from its cluster

## Hubble image commemorates 25th anniversary



JASA/ESA/THE HUBBLE HERITAGE TEAM (STScI/AURA)/A. NOTA (ESA/STScI)/THE WESTERLUND 2 SCIENCE TEAM

**CELESTIAL FIREWORKS.** To celebrate 25 years since the Hubble Space Telescope was launched April 24, 1990, scientists released an image showcasing some of the Milky Way's hottest, brightest, and most massive stars. Westerlund 2, a cluster of about 3,000 stars spanning some 6 to 13 light-years, is only about 2 million years old and alive with activity. Astronomers used Hubble's visible and near-infrared light-gathering capabilities to reveal the nebula of gas surrounding the stars, sculpted by their hurricane-force winds. — **K. F.**

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# Searching for the universe's background glow

From radio waves to gamma rays, the cosmos is awash in the faint light of the extragalactic background. Where does it all come from? **by Liz Kruesi**

**A**stronomers have long wondered how much light the universe holds. Henrich Olbers famously posed the question in the early 19th century: Given the number of stars across an infinite cosmos, why isn't the night sky as bright as the Sun's surface? Olbers' paradox, as it's called, incorporated several other assumptions that have since been proven false, but the topic — Where is all that light? — remains, and it has inspired countless studies to take a census of the universe's radiation.

Arno Penzias and Robert Wilson's accidental discovery of the cosmic microwave background (CMB) — the hiss of the Big Bang's remnant radiation — in 1964 is the most well known. But how much have you heard about the rocket that Riccardo Giacconi (then at the Massachusetts Institute of Technology) and three colleagues launched June 18, 1962? While looking for

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*Astronomy Contributing Editor **Liz Kruesi** writes about the wonders of the cosmos from Austin, Texas.*





**The extragalactic background hides behind many closer, brighter sources. This picture captured from La Silla Observatory in Chile shows the Milky Way and the Magellanic Clouds shining to the right, zodiacal light streaking up in the middle, and of course the glow of thousands of stars across the night sky.** R. WESSON/ESO

X-rays emitted from the Moon (a result of the Sun's X-rays slamming into the lunar surface), they found the first X-ray source outside our solar system (Scorpius X-1), in addition to a pervasive X-ray glow across the night sky.

And the CMB discovery prompted astronomers to look for a background of infrared light, produced by galaxies that lived long ago. In 1967, two prominent CMB researchers at Princeton, P. James E. Peebles and R. Bruce Partridge, calculated the effect of this glow.

While the CMB carries information of the 380,000-year-old cosmos, when that light flew free, scattering from the newly formed hydrogen atoms, astronomers have found in the past several decades that it's far from the only background light in the universe. "It might be, on first sight, less sexy to study all that happens between that last scattering surface and us," says Jonathan Biteau of the University of California, Santa Cruz, "but it's actually almost all the history of the universe. We are studying 13 billion years of star formation, galaxy formation, and emission across all wavelengths."

This extragalactic background light, or EBL, holds the history of star birth and death, active black holes, galaxy evolution, and everything else in the cosmos. But it's hard to detect, and astronomers have had to find creative ways to measure it.

## The universe glows

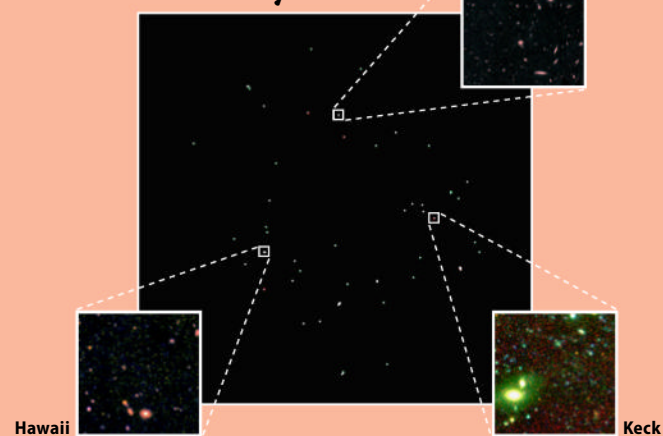
Our eyes can see only a tiny portion of the light that nature makes. The full regime of radiation is called the electromagnetic spectrum, and it spans an enormous scale. Low-energy radio emission can have wavelengths as long as several kilometers, while high-energy gamma rays have wavelengths a few trillionths of a meter (called picometers). Visible light, what we can see, spans just a few hundred billionths of a meter (called nanometers). And at every one of those wavelengths, background light glows.

Astronomers have launched rockets, balloons, and spacecraft and combined those observations with ones from ground-based instruments to measure the brightness of the background light at every wavelength. When they look at the intensity of the EBL per



The bright band of zodiacal light seen here is caused by sunlight reflecting off the billions of tiny dust grains scattered across the disk of the inner solar system. Extragalactic background hunters must peer through this debris to see the much fainter background glow of the cosmos. Z. BARDON/ESO

## Invisible X-ray sources



NASA/GSFC (MUSHOTZKY, ET AL)/UNIVERSITY OF HAWAII/L. COWIE

Even the most sensitive optical telescopes, including the Hubble Space Telescope, Keck Observatory, and the University of Hawaii's 2.2-meter telescope, show no central source where Chandra reveals numerous X-ray targets contributing to the extragalactic background.

wavelength, they find multiple peaks in the spectrum. The largest bump, and thus the brightest portion, is the CMB. The weakest background is the radio, at wavelengths longer than the CMB. This EBL is so faint and difficult to see, in fact, that little research has actually been done to characterize it. The rest of the backgrounds are, in order of brightest to faintest: infrared, optical, ultraviolet, X-ray, and gamma-ray.

The infrared, visible, and ultraviolet backgrounds all come from the same initial source: stars. During the majority of its life, a star converts hydrogen to helium within its core. This process releases photons that, after thousands of years bouncing off dense material within the star, finally penetrate the surface to fly toward our telescopes. While stars, like any warm object, glow across a wide range of light, many shine brightest in the optical. Those like the Sun peak in yellow-green, hotter stars in blue, and cooler stars in lower-energy red. The hottest, most massive stars spew ultraviolet light.

That radiation doesn't all fly freely once it leaves a star's surface, though. Instead, some collides with dust, which absorbs the light and heats up. The dust then emits radiation in the infrared. Another source of infrared light hidden in the EBL are the first stars. While these suns glowed in visible and ultraviolet when they existed a measly few hundred million years into the universe's history, 13 billion years of cosmic expansion since has stretched that light to longer wavelengths — placing it firmly in the infrared regime.

## Counting the light

Researchers measure the background radiation across the infrared, visible, and ultraviolet using both direct and indirect methods. In the former, they take images of the sky, count the amount of light in each region, assume the other patches of sky are similar (because there's nothing special about

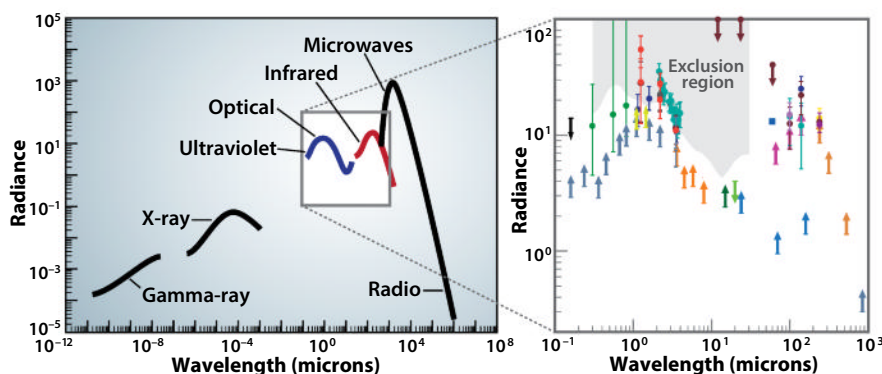
our viewpoint of the universe), and calculate how brightly the cosmos glows at each wavelength.

Sounds straightforward, right? Except that they need to tease out the whispers of the EBL from the screams of light produced by our solar system and galaxy.

Earth orbits the Sun within a pancake of dust composed of the remnants of collisions between asteroids and the material shed by comets. Sunlight scatters off these dust particles, creating what's called the zodiacal light, glowing at infrared and visible wavelengths. Unfortunately, this glow is much brighter than the EBL — about 1,000 times brighter, in fact, says Clemson University's Marco Ajello: "A small —  $\frac{1}{1,000}$  — error in accounting for the zodiacal light might translate into overestimating the EBL by a factor of two!"

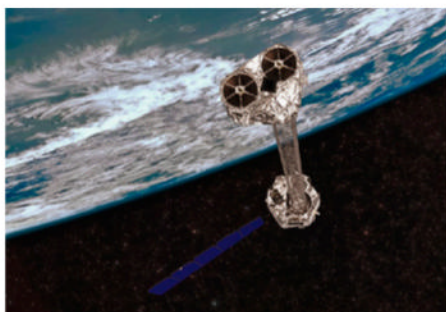
And it gets worse: Subtracting out the zodiacal light is complicated. "Earth moves through that pancake, it goes up and down inside of it, because its orbit isn't exactly aligned with the plane of the pancake," says Michael Zemcov of the California Institute of Technology. Our planet's movement also produces a wake in the

## Measuring the cosmos: a group effort



The extragalactic background has multiple peaks across the full electromagnetic spectrum (left). The microwave background is the most familiar — and has the strongest peak. But zooming in on the ultraviolet/optical region of the spectrum (right) reveals a wealth of different sources contributing to the universe's background glow. ASTRONOMY: ROEN KELLY, AFTER ASANTHA COORAY (UNIV. OF CALIFORNIA, IRVINE)





**The NuSTAR space observatory alone works to probe the highest-energy “hard” X-rays. But many sources still lie beyond NuSTAR’s ability to study, and no future hard X-ray observatories are planned. NASA/JPL-CALTECH**

zodiacal dust, further complicating the signal. Astronomers subtract this signal as best they can using current data, but what they really need is an instrument that can measure the EBL from outside the asteroid belt, where the zodiacal light cuts off. Unfortunately, no such mission is planned.

Beyond the zodiacal light, scientists still must subtract the glow of all the stars in the Milky Way, plus the dust, gas, and all other celestial sources in our galaxy. Getting at the EBL means they need to understand everything between that light and Earth.

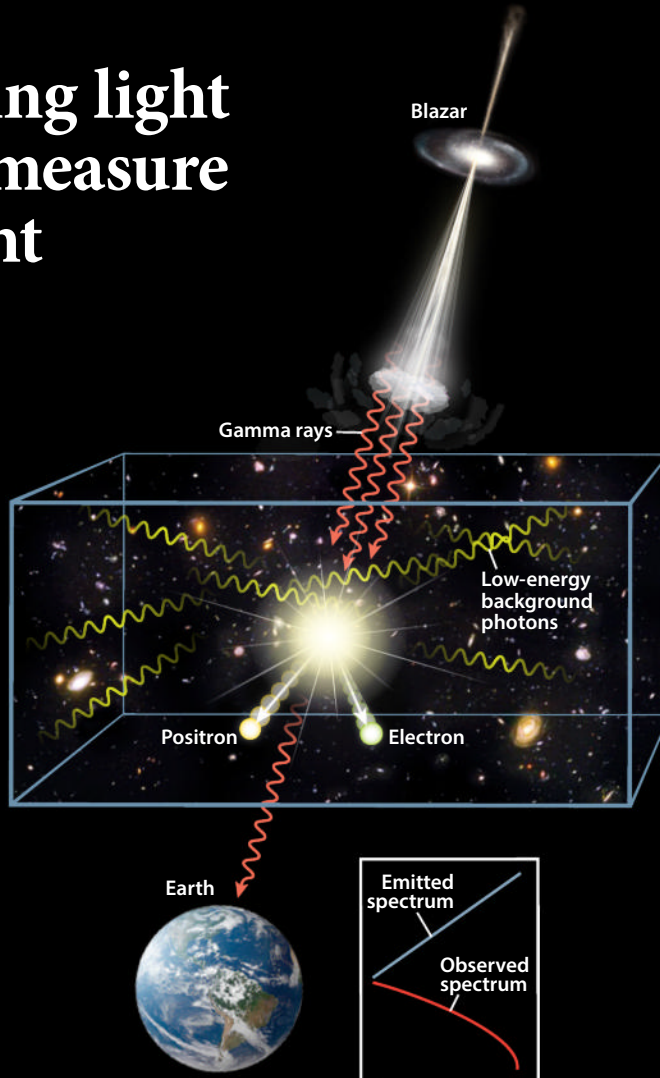
Calculating the portion of the infrared background that originates from the first stars takes the subtractions even further; astronomers must remove the light from every other galaxy that telescopes can resolve — which is a lot! Kari Helgason of the Max Planck Institute for Astrophysics is looking for this glow. “We see a clear fluctuation signal that cannot be explained in terms of known sources,” he says. “The question is: Are we truly getting a glimpse of the early universe, or does this signal originate more locally?” Astronomers can’t yet provide an answer.

## An ingenious perspective

The indirect method of probing the infrared, visible, and ultraviolet EBL uses the bright and energetic light from distant “blazars” as if they were headlights failing to cut through fog. A blazar, like all active galaxies, has at its heart a supermassive black hole. Surrounding the black hole is a disk of gas and dust, material the black hole’s gravity is pulling in for a lengthy meal. But that environment is chaotic, and it launches jets of high-speed particles and radiation perpendicular to the disk. If Earth-based telescopes are looking down the barrel of one of those jets, they can probe its contents. In particular, EBL researchers want to use the gamma rays from faraway blazars.

As a high-energy gamma-ray photon travels from its source to a telescope, it can collide with a low-energy EBL photon. The collision converts both photons to an electron and its antiparticle, called a positron. Thus, the gamma ray seems to disappear, the EBL effectively absorbing it. The process leaves an imprint on the blazar’s light that scientists can detect.

# Using light to measure light



**Astronomers can use missing high-energy photons to construct a spectrum of the low-energy extragalactic background (EBL) photons that obscure them. Gamma rays shot out of blazars — active galaxies with massive central black holes — slam into ultraviolet, optical, or infrared EBL photons and — if the energies are perfectly complementary — convert both photons into positrons and electrons.**

If astronomers know how far away that blazar is and can collect its light across a range of wavelengths, they can look at different absorption features in the spectrum. “By reconstructing these features, we can reconstruct the spectrum of the EBL as it is today,” says Biteau. This technique doesn’t depend on cataloging specific light sources — like stars or black holes. Instead, it probes the entire amount of background light between each blazar and Earth.

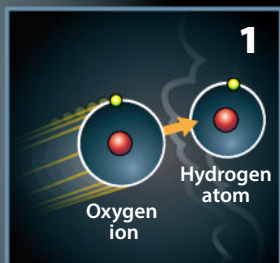
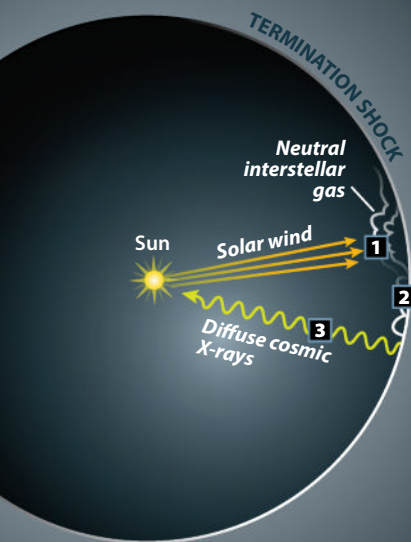
This absorption technique hinges on a distinct relationship: The more energetic the gamma ray, the less energetic the photon it requires for the process. This association exists because there’s a specific energy at which two photons will convert to an electron-positron pair; if the energy of one of the photons increases, the energy in the other must decrease. The most energetic gamma rays probe the infrared EBL, while the less energetic ones map the ultraviolet regime.

By collecting gamma rays across many different energies, scientists begin to piece together how much background light exists at different wavelengths. They use two kinds of gamma-ray telescopes for these studies: the space-based Fermi, which looks for lower-energy gamma rays, and ground-based “Cherenkov arrays,” which detect the higher-energy gamma rays.

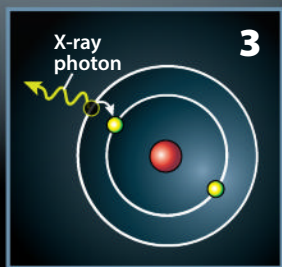
ASTRONOMY: ROEN KELLY, AFTER THE H.E.S.S. COLLABORATION

# Blame the Sun

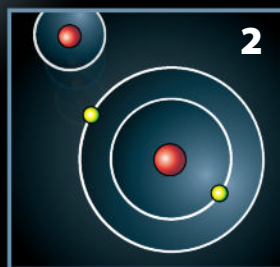
The recently discovered “charge exchange process” explains the local contribution to the diffuse X-ray glow spread across the sky. Oddly, the source of some of the apparent “cosmic” X-rays is **our Sun**. ASTRONOMY: ROEN KELLY, AFTER NASA/CXC/M. WEISS



The solar wind hurls oxygen ions (atoms stripped of their electrons) to the edge of the solar system, where they collide with hydrogen atoms.



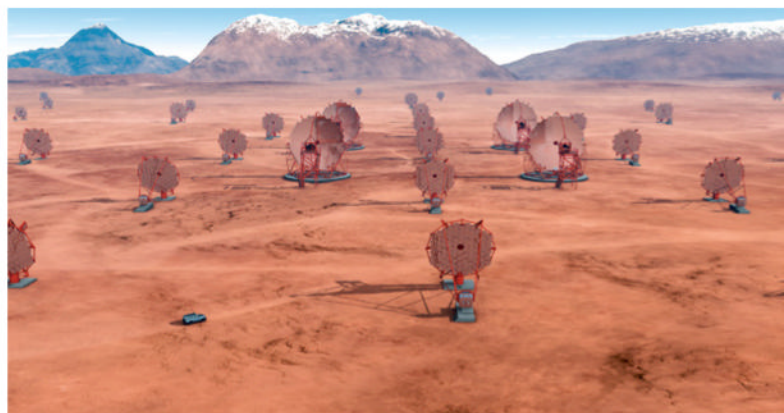
The electron immediately relaxes to a lower energy state, giving off an X-ray as it does. This photon is emitted in a random direction, causing the diffuse glow we observe in the sky.



Oxygen steals an electron (green) from hydrogen, slotting it first into an excited energy state.



The Chandra space observatory examines the middle energy range of X-rays, allowing astronomers to form a fuller picture of the radiation streaming from black holes. NASA/CXC/NGST



When complete in 2020, the Cherenkov Telescope Array in Namibia will revolutionize gamma-ray astronomy. DESY/MILDE SCIENCE COMM./EXOZET

Fermi data contain hundreds of blazars that astronomers can use to study the EBL. In 2012, Ajello and colleagues looked at 150 of them and measured the intensity of the ultraviolet EBL at three distinct time periods: 4.1, 8.8, and 11.2 billion years after the Big Bang. They’re currently analyzing another set of data that, optimistically, according to Ajello, will sample the EBL at 10 different epochs, reaching back to just 1.5 billion years after the universe’s beginning.

The ground-based arrays look for gamma rays with energies a trillion times that of visible light. Occasionally one of these photons interacts with a molecule in Earth’s atmosphere and sets in motion a shower of lower-energy particles, some of which race to the ground faster than the speed of light through air. This creates a bunching up of blue and ultraviolet light due to the Cherenkov effect; it’s similar to the shock wave that forms when a jet travels faster than the speed of sound. Special ground-based telescope arrays collect the blue and ultraviolet light, which scientists can use to determine the source direction of the original gamma ray and what its energy was.

For now, the telescopes studying these more energetic gamma rays — VERITAS in Arizona, H.E.S.S. in Namibia, and MAGIC in La Palma — have only a few dozen blazars for the technique. But that will change dramatically once the Cherenkov Telescope Array comes online in 2020. This cutting-edge observatory will find more of the highest-energy blazars and also will be able to study

the regime that Fermi currently looks at. “The hope for the future-generation experiment is to be able to track the EBL by layers, by taking more and more distant sources and being able to reconstruct the EBL for different distances,” says Biteau. “This would allow us a technique to reconstruct the star formation story.”

## Bright black holes

The EBL doesn’t just radiate in microwaves through ultraviolet light. Remember Giacconni and colleagues’ discovery of a pervasive X-ray glow in 1962? At first, astronomers considered that the glow could be caused by extremely hot clouds of extragalactic gas, but this theory didn’t fit in with other observations. They have since managed to account for the bulk of the X-ray background by adding up the light from actively accreting supermassive black holes, but they still have a portion of the EBL that doesn’t fit these sources.

Observations from the Chandra X-ray Observatory proved that active galaxies are responsible for most of the middle range of X-rays, between about 1 and 10 kiloelectron volts. But the X-ray EBL peaks at slightly higher energies (equivalent to shorter wavelengths), between 20 and 30 keV — a range that hasn’t been studied well yet.

Astronomers with the NuSTAR space observatory are studying these “hard” X-rays now and comparing how different sources look to Chandra and NuSTAR, says the project’s principal investigator, Fiona Harrison. They will piece together details of black holes seen



at different energies to see if the EBL peaks in hard X-rays purely because gas and dust block the lower-energy X-rays from detection, or if black holes preferentially spew higher-energy X-rays.

Unfortunately, NuSTAR only will be able to resolve about half of the EBL's intensity at these higher energies into individual sources, likely leaving the question open for decades to come. There are no new hard X-ray observatories on the horizon.

The lowest-energy X-rays, below 1 keV, seem to result from two contributors. While part originates from active black holes and other energetic events, our Sun's wind of charged particles is responsible for the rest, meaning this glow is actually a combination of extragalactic background light and nearby light. This part of the EBL mystery was just resolved — several studies in the past few years detected the “charge exchange process.” It occurs when the solar wind throws oxygen atoms stripped of their electrons, called “ions,” into the solar system. Beyond Jupiter, those particles slam into neutral hydrogen atoms, the predominant material in the cosmos. “What tends to happen is the electron gets yanked off the hydrogen atom and forcibly reattached to the oxygen ion, but it does so at a fairly excited level, and it sort of falls its way down, emitting photons as it goes,” explains Randall Smith of the Harvard-Smithsonian Center for Astrophysics. Those photons are low-energy X-rays.

And while gamma rays beamed from blazars are used to study lower-energy parts of the EBL, there is also a diffuse glow of gamma rays coming at Earth from all directions. Astronomers follow the direct observation, or counting, method to measure this background gamma-ray light and determine if it can be fully accounted for by known astrophysical sources. The culprits are very likely a combination of extreme events, like actively feeding black holes and stellar explosions, in addition to more routine sources, such as star-forming and regular galaxies (gamma-ray photons are a byproduct of cosmic-ray production, which happens in all galaxies). “But our uncertainties are still fairly large,” says Ajello, “so there could be some other population or some other mechanics.” Some researchers, for example, propose that part of the gamma-ray EBL might come from particles that make up the mysterious dark matter annihilating other such particles.

## Adding it all up

Scientists can use their indirect studies of missing gamma rays to put upper limits on how much radiation exists, while direct, or counting, measurements of the light from galaxies give scientists a lower limit of light's intensity. By comparing the two techniques, scientists can figure out how much energy the EBL holds — and, perhaps even more importantly, find if there are any surprises. There's always the possibility that the upper limits point to extra light in the cosmos, perhaps due to an inherently diffuse glow that does not arise from discrete sources such as stars or black holes. It could even indicate undiscovered physics. An even bigger surprise would be if astronomers find less radiation with the blazar-as-headlights technique than with the galaxy counting



**This artist's concept of an active black hole shows the powerful jets streaming out of the disk. If aligned toward the observer, it is called a blazar. Such objects can teach astronomers about the extragalactic background pervading the intervening space. DANA BERRY FOR ASTRONOMY**

method. “The only way this could happen is if, when gamma rays travel from the distant source to us, they in some way circumvent this absorption mechanism,” says Frank Krennrich of Iowa State University. “Basically, they're tunneling through the diffuse EBL.” This idea certainly excites researchers. And the possibility of further mysterious sources contributing to the EBL is one of the main reasons astronomers need to measure the backgrounds precisely.

At higher energies, the amount of background radiation puts constraints on the number and characteristics of active black holes and other energetic objects. Working with lower energies of the EBL, scientists can constrain the contributions from different sources, as well as compare their infrared, optical, and ultraviolet measurements to computational models. These comparisons inform astronomers simulating cosmic structure formation across the universe's history, who will need to produce all the many galaxies and thus stars that create the glow that observational astronomers measure. “The EBL can also provide strong constraints on the cosmological parameters,” adds Ajello, “like the expansion rate of the universe.”

Until new observatories open their eyes, astronomers will continue to refine these models and tweak their analysis techniques. Understanding the light that pervades the universe has been a many-decade — and perhaps even many-century — quest, and it promises to continue for years to come. 🔭



**The H.E.S.S. telescope in Namibia measures gamma rays from distant blazars. H.E.S.S. COLLABORATION/CHRISTIAN FÖHR**



WATCH A BLAZAR'S GAMMA RAYS ENCOUNTER THE EXTRAGALACTIC BACKGROUND ON THEIR WAY TO EARTH AT [www.Astronomy.com/toc](http://www.Astronomy.com/toc).



# A fresh look

Seven spacecraft — two on the ground and five circling above — continue to scour the Red Planet for signs of ancient water and conditions conducive to life.

by Jim Bell

**M**ars— the latest international hotspot. Although that designation might seem a bit far-fetched, it seems less so if you consider the seven spacecraft now operating at the Red Planet and the five more being readied to go as scientific tourists. Robotic emissaries from Earth have occupied Mars continuously since 1997, and the missions currently active date back to 2001. This is the busiest, most fruitful, and most exciting time in the history of Mars exploration. The armada of spacecraft delivers a steady stream of data to planetary scientists that has led to important discoveries but also raised intriguing new mysteries.

## The ground truth

Two rovers — Opportunity and Curiosity — continue to return sensational scientific information from the surface. Opportunity, which landed in January 2004 and celebrated its 4,000th martian day, or sol (one sol equals about 1.03 Earth days), in April 2015, surpassed the 26.219-mile (42.195 kilometers) distance of a marathon a month earlier. The rover's science team, working on the planet's surface virtually through the robot, is now exploring the eroded rim of an ancient impact crater called Endeavour.

NASA orbiters previously had detected evidence for clay minerals on the rim of this 14-mile-wide (22km) crater. Opportunity has sampled those clays and found abundant evidence for

mineral-filled veins containing gypsum. Both substances provide further proof that groundwater and perhaps even surface water once existed on this part of Mars. The clays, in particular, suggest that some of this water could have been comparable to fresh water on Earth rather than the mildly acidic water inferred from Opportunity's earlier discoveries at Eagle, Endurance, and Victoria craters.

Even though Curiosity is the new kid on the block, having landed in August 2012, it surpassed its 1,000th sol in late May 2015. The sophisticated rover is now exploring the lower slopes of Mount Sharp, the looming 3-mile-high (5km) mountain of layered sedimentary rocks inside Gale Crater that drew the rover team to this landing site. Mount Sharp's layers record important parts of Mars' early warmer and wetter history. Curiosity's mission is to decipher that record in detail, layer by layer if need be, to learn as much as possible about the Red Planet's potential past habitability.

Like its predecessors, Opportunity and Spirit (which ceased transmissions in March 2010), Curiosity has found and continues to find ample evidence that both surface and groundwater once flowed on Mars. Recently revealed signs of that water include swarms of mineral-rich veins created when moving groundwater deposited materials that filled fractures in rocks. Other fresh discoveries of ancient water involve the detection of the iron-oxide mineral hematite,



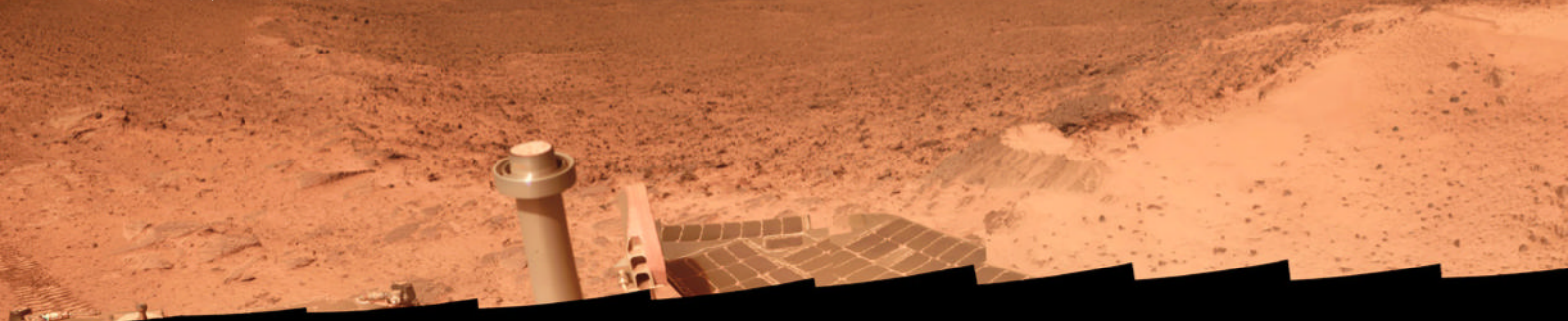
# at MARS



NASA's Curiosity rover poses for a selfie on Mount Sharp in January 2015. This vista combines dozens of images captured by a camera that sits at the end of the rover's robotic arm. (Ground controllers positioned the arm so it would be out of the mosaic's frames.) The rim of Gale Crater appears at the top right of this image, and the peak of Mount Sharp is at the top left. NASA/JPL-CALTECH/MSSS



NASA's Opportunity rover captured this panorama from the rim of Endeavour Crater in January 2015. The clay materials Opportunity has found at Endeavour imply that groundwater once existed in this area. NASA/JPL-CALTECH/CORNELL UNIVERSITY/ARIZONA STATE UNIVERSITY



Curiosity continues to explore the layered rocks on Mount Sharp's lower slopes. In September 2014, the rover drilled its first hole on the mountain to collect samples for onboard analysis. The hole measures 0.63 inch (1.6 centimeters) across and 2.6 inches (6.7cm) deep. NASA/JPL-CALTECH/MSSS



Curiosity discovered these two-toned mineral veins on the lower slopes of Mount Sharp in March 2015. They apparently formed when water flowed through fractured rock and deposited minerals in the cracks. The veins appear as a network of ridges, each of which measures up to 2.5 inches (6 centimeters) thick and half that in width. NASA/JPL-CALTECH/MSSS



The Mars Reconnaissance Orbiter captured Curiosity and its tracks as it trekked through layered deposits in April 2014. The rover (arrow) appears blue in this image's exaggerated color.

Planetary scientist **Jim Bell** is a professor in the School of Earth and Space Exploration at Arizona State University in Tempe. He is a member of the Mars Odyssey, Mars Reconnaissance Orbiter, Opportunity, and Curiosity science teams, and is leading the development of the high-resolution zoom cameras for the Mars 2020 mission. He is the president of The Planetary Society and enjoys science writing. His most recent book is *The Interstellar Age* (Dutton, 2015).

formed when water alters basaltic volcanic rock, and jarosite, an iron- and sulfur-bearing mineral that can arise when volcanic rock interacts with mildly acidic water.

These kinds of mineral discoveries coupled with spectacular images of finely layered sandstones and mudstones (fine-grained sedimentary rocks that typically form in water's presence) are beginning to paint a clearer picture of Mount Sharp. Scientists now suspect it is an enormous accumulation of sediments deposited in an ancient lake that periodically filled Gale Crater early in the planet's warmer and wetter history. It's an exciting hypothesis, but Curiosity needs to do a lot more climbing and sampling of additional layers to fully test it and tease out more details of the habitability of that possible ancient lake.

Curiosity's measurements of the martian atmosphere have been no less thrilling. A detailed search for methane early in the mission came up essentially blank, but in late 2013 the rover observed a tenfold spike in the abundance of this gas followed by a quick return to near-zero levels. Are there localized sources of this simple organic compound on Mars, perhaps a byproduct of geological processes such as a reaction

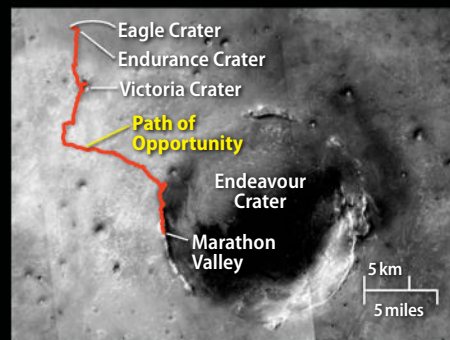
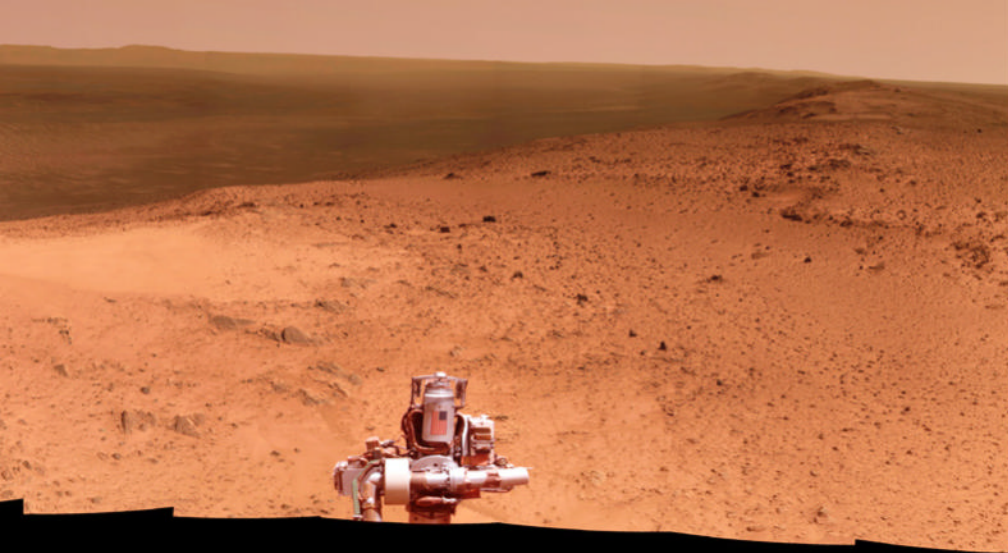
between water and subsurface rock? Or could it be from some subsurface biological process? Although the latter seems unlikely, mission scientists don't want to discount any possibilities until they perform additional measurements and analyses.

## The view from above

In the meantime, five active probes — three from NASA, one from the European Space Agency (ESA), and one from the Indian Space Research Organization (ISRO) — are plying the orbital seas above Mars. Using a variety of sophisticated instruments, these spacecraft are scouting the planet's geology, mineralogy, and atmospheric composition as well as searching for landing sites for future rovers and surface probes.

The most venerable of this quintet, and indeed the longest-operating spacecraft ever to explore the Red Planet, is NASA's Mars Odyssey. Since arriving in polar orbit in 2001, Mars Odyssey has circled the world nearly 60,000 times. In the process, it has discovered water ice in the south polar cap, found evidence that melting snow carved some geologically recent gullies, and helped find landing sites for Spirit and Opportunity.





NASA/JPL-CALTECH/MSSS/MMNHHS;  
ASTRONOMY: KELLIE JAEGER

On March 24, 2015, Opportunity completed its first marathon when it passed the 26.219-mile (42.195 kilometers) mark on Mars' surface. The journey took more than 11 years and carried the rover from its landing site in Eagle Crater to the rim of Endeavour Crater.

It also has built up an impressive collection of chemical and mineral maps of the surface that have helped scientists understand the distribution of ground ice as well as new details about the planet's geology and mineralogy. Thanks to the mission's longevity, the Mars Odyssey team recently was able to complete a global set of infrared geologic maps at a resolution of around 330 feet (100 meters) per pixel. These are the highest-resolution maps of surface properties yet created for Mars and are helping researchers differentiate bedrock from sediments and dust-covered surfaces.

The second-oldest orbiter is ESA's Mars Express, which went into an elliptical orbit around the planet in late 2003. The spacecraft's instruments have been mapping the geology (in 3-D), mineralogy, and atmospheric chemistry of Mars during each close pass ever since. They have discovered minerals that can form only in the presence of water, vast amounts of water ice beneath the martian surface, and lava flows that might be only a few million years old. The High Resolution Stereo Camera continues to crank out spectacular topographic maps of volcanoes, craters, and canyons across the planet. The 3-D images are helping scientists understand the details of past geologic processes and adding key information to the search for future landing sites.

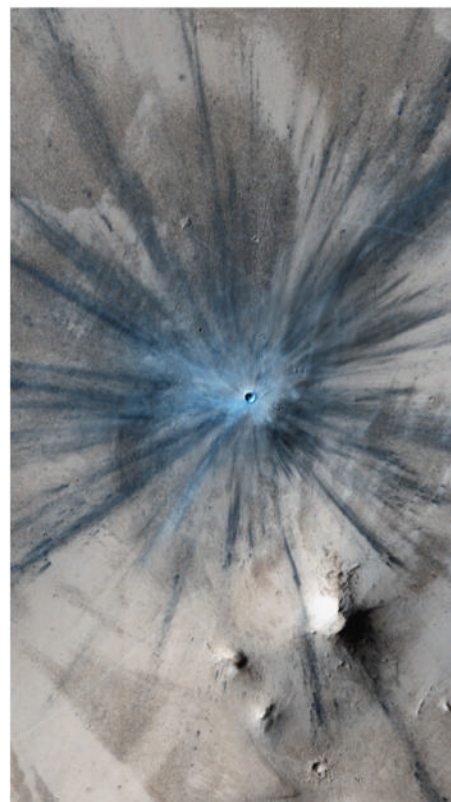
The Mars Reconnaissance Orbiter (MRO) ranks as NASA's most prolific Mars orbiter yet. Since it arrived in its circular polar orbit in 2006, the spacecraft has returned more than 30 terabytes of data — more than all other Mars missions combined. MRO captures the sharpest details from orbit and has helped planetary scientists map Mars' mineralogy and subsurface structure. The probe has found buried glaciers and the clay-rich minerals that led Curiosity's science team to Gale Crater.

The mission's Context Camera has imaged more than 90 percent of the martian surface at a resolution of about 20 feet (6m) per pixel. An even higher-resolution camera, the High Resolution Imaging Science Experiment, helps scientists study intricate details in small gullies apparently created by seeping water, identify fresh impact craters formed within the past decade, and even spot alien spacecraft parts on the surface — most recently, the likely wreckage from the 2003 crash of ESA's Beagle-2 lander.

## The new arrivals

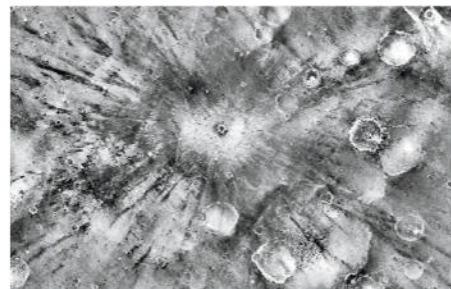
Two rookies recently joined these three veteran orbiters. ISRO's Mars Orbiter Mission (MOM), also called Mangalyaan, is India's first interplanetary mission. And when it entered Mars orbit in September 2014, that nation became the first to achieve success at the Red Planet on its first try. MOM's primary purpose is to test basic spacecraft and instrument capabilities as well as ISRO's ability to journey to Mars and operate successfully from orbit there. But in the process of demonstrating these technologies and skills, the spacecraft has captured some stunning color photos of the martian surface and atmosphere from its highly elliptical orbit.

NASA's newest artificial martian satellite arrived two days before MOM. The space agency designed the Mars Atmosphere and Volatile Evolution (MAVEN) orbiter specifically to study the Red Planet's atmosphere and especially the way it interacts with the stream of high-energy particles emitted by the Sun known as the solar wind. One of the mission's main goals is to test the hypothesis that the solar wind slowly eroded ancient Mars' thicker and warmer atmosphere, perhaps after the planet's core solidified and its early magnetic field disappeared. Mars once had a



NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA

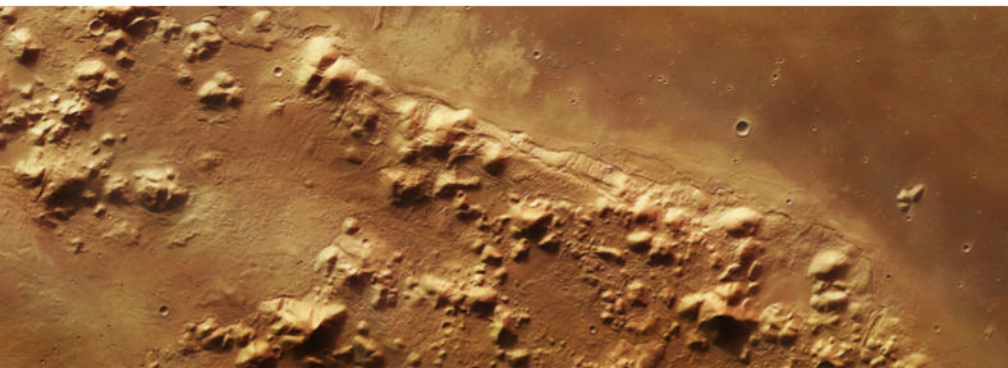
NASA's Mars Reconnaissance Orbiter captured this impact crater, which formed in the past five years. This enhanced-color close-up reveals the 100-foot-wide (30 meters) scar and debris that spreads up to 9 miles (15 kilometers) away.



NASA/JPL-CALTECH/ARIZONA STATE UNIVERSITY

Scientists working with Mars Odyssey data recently created the highest-resolution global map of martian surface properties, in which warm areas appear bright and cool regions dark. This tiny section highlights the 4.3-mile-wide (6.9 kilometers) impact crater Gratter.





**The European Space Agency's Mars Express satellite captured this complex region of isolated hills and ridges in the southernmost section of Phlegra Montes in the planet's northern hemisphere. The probe's High Resolution Stereo Camera snapped this scene in October 2014 at a resolution of about 50 feet (15 meters) per pixel. ESA/DLR/FU BERLIN**

strong magnetic field, a discovery made by NASA's earlier Mars Global Surveyor mission, but no longer does. Will MAVEN find that this is why Mars evolved into the cold, dry world it is today?

Early science results from MAVEN include the surprising discoveries of an auroral glow lower in the atmosphere than scientists expected and a dust layer much higher in the atmosphere than expected. Some researchers have suggested that the absence of a shielding magnetic field could allow the solar wind to penetrate deeper before it initiates the aurora. The origin of the high-altitude dust remains a mystery, however. Is it dust from Mars lofted upward by strong atmospheric currents? Or could it be dust raining down from the martian moons, Phobos or Deimos, or from streams of cometary dust? Scientists plan to test these and other hypotheses with additional MAVEN observations perhaps augmented by other orbiters.

## Comet encounter

MAVEN and the other active spacecraft had front-row seats to one of 2014's most exciting astronomical events — October's close encounter between Mars and Comet Siding Spring (C/2013 A1). Although the comet's icy nucleus would miss the planet by approximately 87,000 miles (140,000km), astronomers predicted that its extended envelope would pass right over Mars and intermingle with its atmosphere.

Cometary impacts and near-misses happen rarely, but they can teach us a lot about planetary atmospheres and comets themselves. Scientists remember vividly when Comet Shoemaker-Levy 9 collided with Jupiter in 1994, a dramatic celestial fireworks show that provided new information about the giant planet's cloud layers as well as the nature of high-speed impacts. Indeed,

researchers studying the February 2013 meteor explosion over Chelyabinsk, Russia, analyzed the event using computer models developed partially from the Shoemaker-Levy 9 impact. Would Siding Spring deliver a similar show, or a show at all? No one was sure how the comet, which originated in the distant Oort Cloud, would behave.

MAVEN had perhaps the best view, and its science team commanded the spacecraft to observe the comet both before and after its Mars encounter. Although the probe's highly sensitive ultraviolet instruments are optimized to study the planet's upper atmosphere and aurorae, scientists often use these same kinds of tools to study comets.

There was some danger in making these observations, however. High-speed impacts by even tiny chunks of ice or dust ejected by the comet could cause a catastrophic failure of spacecraft components. To minimize the risk, mission managers manipulated MAVEN's orbit to "hide" the

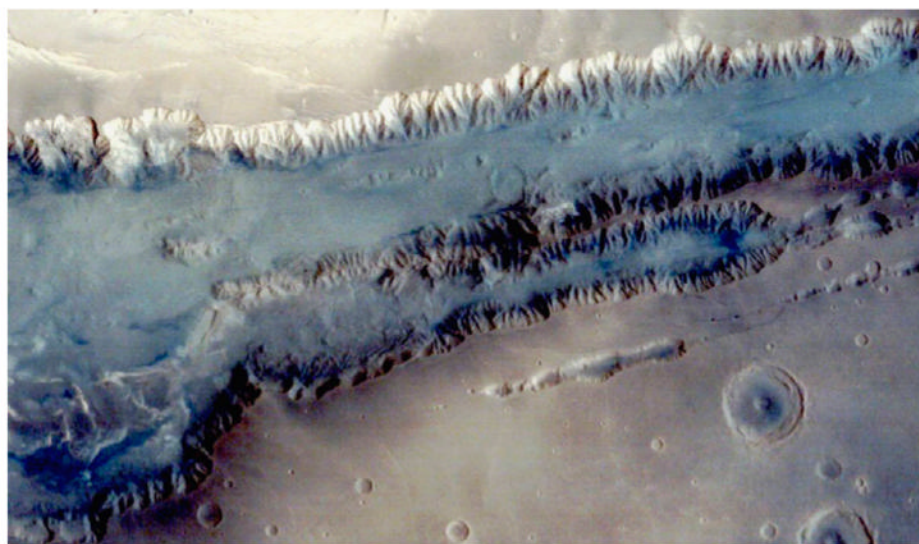
spacecraft behind Mars during the comet's closest approach. Better safe than sorry, especially since MAVEN had arrived at Mars just a month earlier. As the comet swooped past the Red Planet, controllers of the other Mars orbiters similarly protected their probes.

The spacecraft delivered a treasure-trove of information about Siding Spring. MAVEN, MRO, and Mars Express all detected strong increases in the number of electrically charged atoms in Mars' upper atmosphere. These ions formed as the comet's dust and gas slammed into the planet, stripping the atoms of electrons. MAVEN's ultraviolet instruments captured the bright glow from the comet's magnesium and iron ions, for example, and then the probe sampled these and other ions as it circled back around the planet. These observations were the first direct measurements scientists had ever made of ionized material from an Oort Cloud comet in a planetary atmosphere.

Comet Siding Spring also must have produced an impressive meteor shower. Unfortunately, the cameras on Opportunity and Curiosity were built to image the daytime surface and not the nighttime sky. Their relatively short exposures didn't capture any meteors and rendered the comet as little more than a fuzzy blob.

## Future exploration

Six national space agencies have now launched more than 40 missions to Mars since the first attempt in 1960. Only about half of these proved even partially successful, attesting to the difficulty in exploring the Red Planet. Despite the challenges, however, humans continue to send robotic



**Although India designed its Mars Orbiter Mission only to demonstrate technology, the spacecraft has returned some stunning images since arriving in September 2014. This one shows part of Valles Marineris, a canyon system that spans 2,500 miles (4,000 kilometers) and digs 4.5 miles (7km) deep. ISRO**





**NASA's Mars Atmosphere and Volatile Evolution spacecraft discovered a martian aurora three months after it arrived in September 2014. This artist's concept shows the probe's ultraviolet imager capturing the glow.** NASA/UNIVERSITY OF COLORADO



**The martian armada targeted Comet Siding Spring (C/2013 A1) in October 2014. In this artist's concept, NASA's three orbiters watch as comet material crashes into the atmosphere and ionizes atoms from the deep-space visitor.** NASA/JPL-CALTECH

emissaries and even have started thinking about plans for the first crewed missions, perhaps as soon as the 2030s.

Indeed, several missions in the works have direct connections to the eventual human exploration of Mars. In 2016, NASA will launch *Insight*, a lander based on the successful design of the 2008 *Phoenix* spacecraft. *Insight* will deploy a sensitive seismometer and heat-flow probe to search for signs of seismic or geothermal activity. Is Mars geologically dead or still active? *Insight* is designed to find out during its two-year primary mission, which will start in late 2016.

Also in late 2016, ESA, in cooperation with the Russian space agency, Roscosmos, will deploy the *ExoMars Trace Gas Orbiter*. This spacecraft will study methane and other minor atmospheric gases that might provide clues to the planet's geologic and possible biologic evolution. As part of the mission, the orbiter will deploy an entry, descent, and landing demonstration module called *Schiaparelli*. ESA expects *Schiaparelli* to prove the agency's ability to make a controlled landing on Mars' surface. If it survives touchdown, the spacecraft will conduct a science mission lasting two to



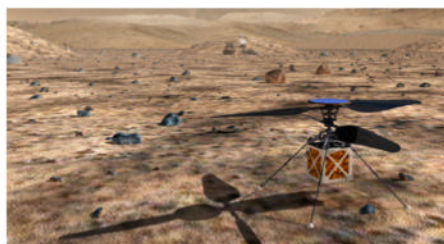
**The dark reddish lines angling to the upper left in this Mars Reconnaissance Orbiter image are active flows extending downhill from Hale Crater's central peaks. Scientists think the flows might be caused by seeping water.** NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA

eight sols designed to study the landing site's atmospheric conditions.

ESA will attempt its first Mars rover, once again in cooperation with Roscosmos, with *ExoMars*. Currently scheduled for a 2018 launch, the rover will use cameras, spectrometers (which analyze elemental composition), radar, and a drill to study the geological history of a past watery environment on Mars.

Understanding the detailed nature of the martian environment is also at the forefront of NASA's plans for its next Mars rover, tentatively called *Mars 2020* after the year of its planned launch. To save money, some 80 to 90 percent of the rover will be constructed from spare parts from *Curiosity*. NASA envisions *Mars 2020* as a first step in a longer-term set of missions designed to bring samples back from Mars. The rover will feature high-resolution cameras, spectrometers, and drilling/coring systems that will allow it to physically sample a variety of surface materials and cache them for potential transport to Earth on future missions.

Many planetary scientists believe that the next major leap in Mars exploration,



**The future of Mars exploration looks as promising as the present. Future rovers may employ a small helicopter to scout ahead, finding features of interest and allowing ground controllers to plot the best driving routes.** NASA/JPL-CALTECH

and a critical step toward eventual human exploration of the Red Planet, will be to bring these carefully selected samples of soils and rocks to Earth for detailed geochemical and biological analysis. Are there chemical compounds in the soils that could degrade space-suit seals or other systems needed for life support? Is martian dust toxic to the human respiratory system in some unanticipated way? Can explorers extract resources such as oxygen and water from common Mars surface materials?

A primary goal of the *Mars 2020* mission is to collect samples that can begin to answer such questions. Engineers are currently working on ways to cache these samples and decide the best way to return them to our planet.

I believe the human fascination with Mars stems in part from the fact that the deeper we look at it, the more we see parallels with our own world's past. Early in its history, Mars was much more Earth-like than it is today. It was warmer and wetter — at least in places. Heat from the Sun, geothermal sources, and impacts provided abundant energy, and the rain of asteroid and comet impacts that pelted Mars and the rest of the planets provided a steady supply of organic molecules.

Water, energy, and organic molecules are the key ingredients needed for life as we know it. Past and present missions have helped us discover that Mars was indeed a habitable world long ago. Upcoming missions, including the first human explorers in the not-too-distant future, will be working to up the ante, trying to find out if Mars was — or still is — not just habitable, but inhabited. ☿



## EUROPAN TIDES

**Q: EUROPA'S OCEAN SITS UNDER A THICK ICE SHELL. IF THIS OCEAN COVERS THE MOON'S SOLID CORE, DOES THE SHELL ROTATE AT A DIFFERENT SPEED?**

*Olle Bernell, Stockholm*

**A:** The short answer is, "Yes, we think it may." And the physics is really interesting!

To the best of our knowledge, Europa has an ice shell of a few to as many as 12 miles (20 kilometers) in thickness, underneath which lies a global 60-mile-deep (100km) liquid water ocean.

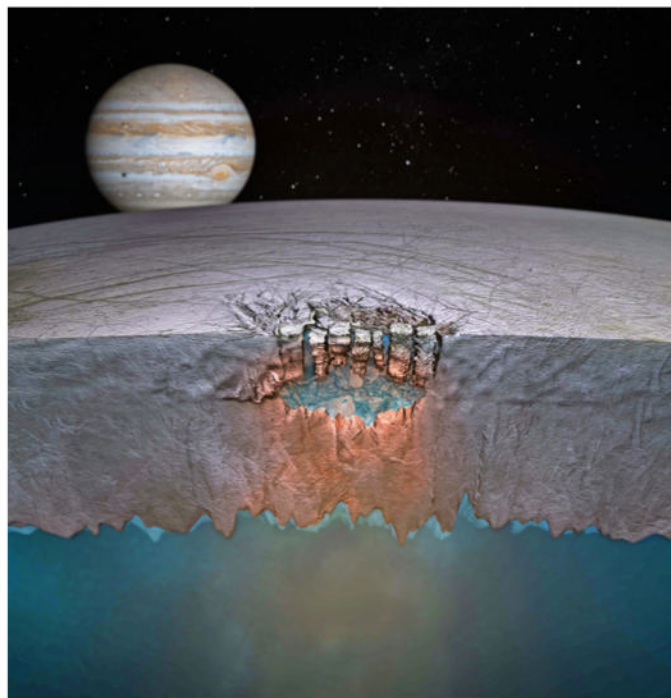
Jupiter and Ganymede's tidal tug-and-pull on Europa distorts it from a perfect sphere and may even cause a rise in the ice shell as high as 100 feet (30 meters) as the moon circles in its 3.55-day orbit. Importantly, Europa's day is the same as its orbital period; in other words, Europa always shows the same face to Jupiter.

Now, if the moon's orbit were a perfect circle, then it would be easy for one European day (one spin on its axis) to match the timing of its orbit around Jupiter. But Europa's orbit is not perfectly circular — it's forced into a slightly elliptical shape by the tug of Ganymede. What this means, as Johannes Kepler taught us, is that when Europa is closest to Jupiter (peri-jove),

it's traveling faster than when it's farthest away from Jupiter (apojove). Well, Europa's rotation cannot easily speed up and slow down to match its changing orbital speed. As a result, when Europa is nearing peri-jove, its tidal bulge lags behind — the rotation hasn't kept pace with the orbital velocity. The gravitational tug from Jupiter on this bulge causes it to move.

This motion is called non-synchronous rotation, and it can occur on any world. But with Europa it could cause the ice shell to float freely on the ocean, making it easier to move. Members of NASA's Galileo spacecraft imaging team compared their images with those from the Voyager mission (a 17-year difference) and found that if the ice shell is rotating nonsynchronously, it is doing so at a rate of more than 12,000 years per full rotation.

Finally, there is another global-scale ice motion called "polar wander." In this case, the entire ice shell is predicted to move as a result of thicker ice regions growing at the poles



**Jupiter's moon Europa is the size of Earth's satellite but may hold as much water as our planet beneath its icy shell. Scientists suspect Jupiter's gravity causes this shell to circle freely atop the ocean, as great ice continents shift and bulge due to jovian tides.** BRITNEY SCHMIDT/DEAD PIXEL VFX/UNIV. OF TEXAS AT AUSTIN

but then becoming unstable and consequently moving out and down toward the equator.

There are lots of interesting predictions about what's happening on, and within, Europa. Now we just need to get back out there to explore this fascinating world!

**Kevin Peter Hand**

*Jet Propulsion Laboratory  
Pasadena, California*

**Q: YOU CAN CLEARLY SEE BOULDERS ON COMETS AND ASTEROIDS. WHAT ARE THESE?**

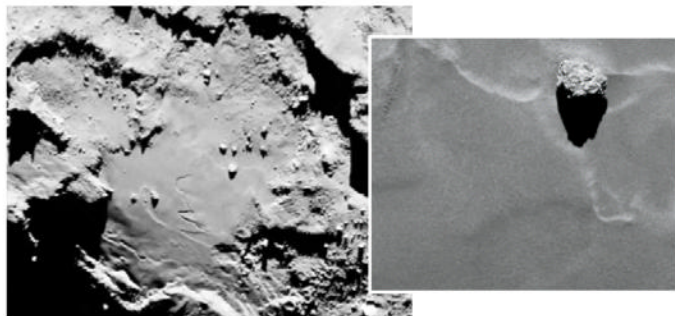
**Skylar Henry**

*Ouray, Colorado*

**A:** Comet 67P/Churyumov-Gerasimenko is half the density of water. This density implies a high porosity in the range of 70 to 80 percent, depending on the assumed dust-to-ice ratio. (You can use 0.9 gram per centimeter for ice and 1.5 to 2 grams per centimeter density for the dust.) Other

comets show densities similar to 67P, but those have been less accurately determined during high-velocity spacecraft flybys and via the plume ejected by the impactor of NASA's Deep Impact mission. Thus, we can infer that cometary material is made of weakly bonded icy dust aggregates with high porosity and low strength.

Images of Comet 67P's cliffs taken with the European Space Agency's Rosetta spacecraft show a heated and cracked surface with long linear features. This material looks sintered — compacted by heating ice without melting it — by bonds among these aggregates, perhaps strengthened by organic compounds. The thermal processing causes cliff collapses, as seen at various places on 67P, and can release single boulders that follow the gravitational downslope and come to rest. In one particular place — the Hapi region between the small and big lobe of Comet 67P —



**The Rosetta spacecraft spotted this boulder on Comet 67P back in September 2014. The rock, named Cheops, may be as many as 150 feet (45 meters) across, and while it looks like any earthly boulder, its formation process is completely alien.** ESA/ROSETTA/MPS FOR OSIRIS TEAM MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA



the boulders seem to form a line by the gravitational attraction from both lobes.

Boulders also might be moved in eruptions when sub-surface gas pressure is released. Such explosions can likely push house-sized boulders basically to any place on the surface.

**Holger Sierks**

Head of Rosetta's OSIRIS instrument  
Max Planck Institute  
Göttingen, Germany

**Q: I HAVE BEEN TRYING TO GET MY HEAD AROUND "THERE IS NO CENTER TO THE UNIVERSE" WITHOUT SUCCESS. CAN YOU GIVE A LAYMAN'S EXPLANATION?**

**Frank Hanour**

Indianapolis

**A:** Few cosmological concepts are harder to grasp than this. To wrap your mind around it, first accept that the Big Bang was not an explosion in space the way we naturally perceive it. Instead, this event included everything. Space itself expanded rapidly.

In fact, the universe was already infinite, as it is now. Energy and matter was everywhere, so there was no special origin point. No center.

Imagine this by drawing lines on a rubber band and pulling at both ends. The lines move apart, but the rubber band is not stretching from the center.

Astronomers first stumbled onto this incredible fact more than a century ago when early measurements showed other galaxies retreating from Earth. But it's now clear that there's nothing special about our position. If you lived in another galaxy, the cosmos would still retreat away in all directions.

Of course, all this expansion raises another question: What is our universe expanding into? Astronomers believe that the observable universe does

not expand into vast fields of nothing, but is instead surrounded by yet more matter and energy.

We can't see this material because it's beyond the cosmic microwave background (CMB) — the oldest light in the universe. The CMB formed about 380,000 years after the Big Bang, when the cosmic soup of particles bouncing around our universe had cooled enough for hydrogen atoms to form.

It's this first light that also gives astronomers a born-on date for existence: 13.82 billion years ago.

**Eric Betz**

Associate Editor

**Q: ASTRONOMERS RECENTLY DISCOVERED THAT SCHOLZ'S STAR PASSED CLOSE TO THE SUN 70,000 YEARS AGO. WOULDN'T ITS GRAVITY HAVE SENT OORT CLOUD COMETS RAINING INTO THE INNER PLANETS?**

**Calvin Harmon III**

St. Marys, Ohio

**A:** Based on the number of long-period comets that enter

the inner solar system, astronomers estimate there are probably trillions of them in the Oort Cloud.

The origins of the Oort Cloud have been debated. Older research suggests these icy bodies were ejected from the solar system during its formation. More recently, some researchers have proposed that interactions with other stars in the Sun's original birth cluster were part of the story, and indeed many or most of the Oort Cloud comets may have even been "stolen" from the vicinity of other stars.

There is a 98 percent likelihood that Scholz's Star passed through the outer, low-density part of the Oort Cloud.

But the "danger zone," so to speak, is likely when another star passes within 20,000 astronomical units (1 AU is the average Earth-Sun distance) of the Sun — the so-called inner Oort Cloud — because there are far more comets in this region. In almost every simulation, Scholz's Star passed well beyond that threshold (only 1 out of 10,000 simulations brought it within 20,000 AU).

Studies do show that a star passing at about 10 times that distance (roughly one parsec) could cause some comets to come into the inner solar system, but there are fewer comets in the Oort Cloud that far out. A recent simulation by a group of German astronomers demonstrated such an encounter would be unlikely to cause a spike in impacts on Earth.

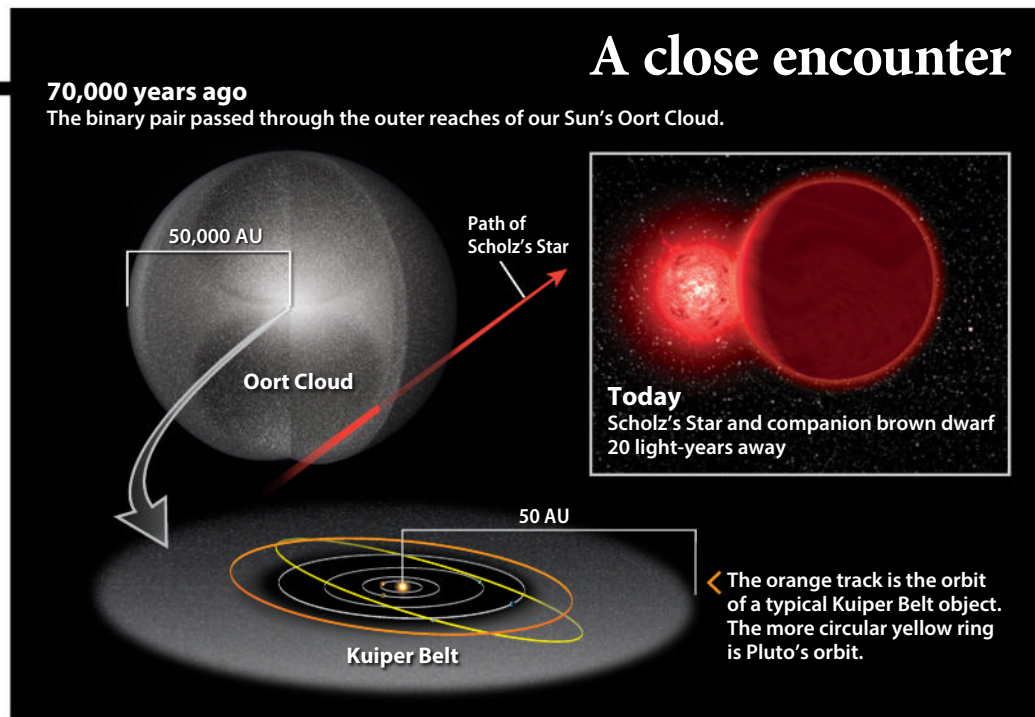
And scientists who study the effects of stellar flybys agree that Scholz's Star would have had similarly little effect on the Oort Cloud and the long-period comet flux.

**Eric E. Mamajek**

University of Rochester, New York

## Send us your questions

Send your astronomy questions via email to [askastro@astronomy.com](mailto:askastro@astronomy.com), or write to Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.



Scholz's Star and its companion brown dwarf likely passed within the outer reaches of the Sun's Oort Cloud, but scientists don't believe the encounter would have sent comets shooting into the solar system.

NASA/MICHAEL OSADCIW (UNIVERSITY OF ROCHESTER); ILLUSTRATION: T. REYES

# August 2015: Perseids reign supreme



The 2015 Perseid meteor shower promises to put on its best show of the past five years. This image shows a 2013 Perseid fireball taken from Wugongshan Mountain in China. LUO CHENG

If watching bright meteors rain down on a warm summer's night is your idea of astronomical bliss, this is the month for you. The annual Perseid meteor shower peaks August 12/13 under ideal conditions. With the Moon completely absent from the night sky, observers at dark sites can expect to see up to 100 "shooting stars" per hour.

For those who prefer viewing planets, the month has its own rewards. Evening twilight in early August offers fleeting glimpses of Mercury, Venus, and Jupiter. Then, once darkness settles in, beautiful Saturn takes center stage. The overnight hours belong to Neptune,

**Martin Ratcliffe** provides planetary development for Sky-Skan, Inc., from his home in Wichita, Kansas. Meteorologist **Alister Ling** works for Environment Canada in Edmonton, Alberta.

which comes to opposition and peak visibility in August, and Pluto, which reached the same point relative to Earth just a month earlier. Shortly before dawn at August's close, Venus returns to view after a three-week pause while Mars comes back after a four-month hiatus.

Head outside shortly after sunset as August begins, and you might catch a trio of solar system objects. **Jupiter** will be the easiest to spot. From 30° north latitude, the giant planet stands 6° high in the west a half-hour after sundown. Shining at magnitude -1.7, it should barely peek through the bright twilight. **Venus** gleams even brighter, at magnitude -4.4, but lies to Jupiter's lower left at just 2° altitude. Magnitude -1.2 **Mercury** resides to the lower right of Jupiter and is just 1° high — invisible without

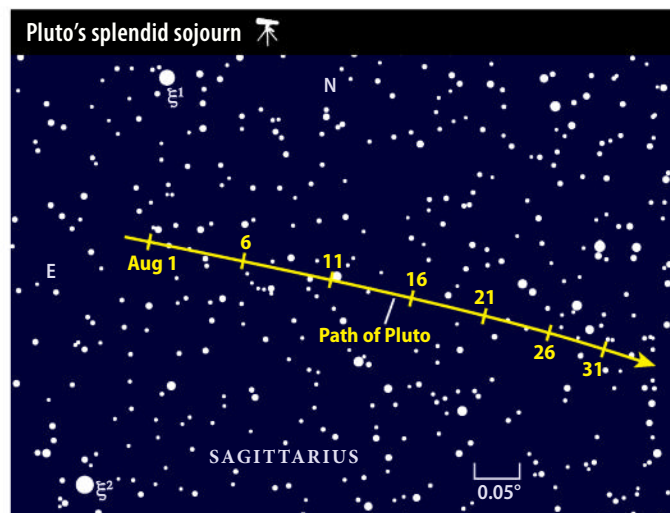
binoculars and near-perfect viewing conditions.

The planets appear higher the farther south you live. From equatorial regions, for example, Venus and Jupiter appear side by side and some 10° above the horizon 30 minutes after sunset. These two

drop out of sight by the end of August's first week, though you still might catch Jupiter within 1° of Mercury on the 6th. Venus slides between the Sun and Earth on August 15, while Jupiter passes on the Sun's far side on the 26th.

Mercury fares significantly better as the month progresses because its angular separation from our star increases. Look for it August 16 when a 2-day-old crescent Moon lies 5° to its left. By the 31st, Mercury climbs 7° high in the west a half-hour after sundown. Glowing at magnitude 0.1, it won't be obvious unless you use optical aid. Through a telescope, the innermost planet then appears 7" across and about 60 percent illuminated.

Observers will have a far easier and more rewarding time with **Saturn**. The ringed planet lies some 30° above the southern horizon as darkness falls August 1 and remains on view until 1 A.M. local daylight time. Its westward motion relative to the



Everyone's favorite dwarf planet glows at 14th magnitude in Sagittarius, close to magnitude 3.5 Xi<sup>2</sup> (ξ<sup>2</sup>) Sagittarii. ALL ILLUSTRATIONS: ASTRONOMY: RICK JOHNSON



## RISINGMOON

### A ram makes its mark

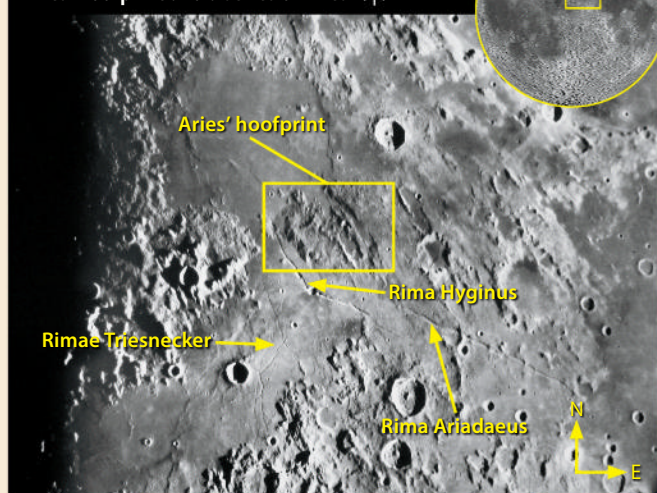
When most amateur astronomers hear the name “Aries,” they immediately think of the zodiacal constellation of the Ram. But lunar observers can be forgiven for having second thoughts. Although Aries the Ram may never have set foot on the Moon, it’s easy to imagine that he left a large hoofprint on the surface.

On the evening of August 21, check out the region along the terminator — the dividing line between sunlight and darkness on the Moon’s surface — just north of the lunar equator. The major features here are a series of long, narrow channels known as rilles, and in particular Rima Ariadaeus, Rima Hyginus, and the rille system Rimae

Triesnecker. But what really catches the eye here shortly after sunrise is a charming feature dubbed “Aries’ hoofprint.” A combination of brightly lit mountains straddled by two deep channels of dark lava creates this striking play of light and shade. At low power with the entire Moon in view, the hoofprint stands out.

Don’t expect to see this feature labeled on lunar maps. After all, it’s just a jumble of mountains left over from the great impact that created the Imbrium Basin with a channel of mare lava on either side. While you’re in the area, spend some extra time with Rima Hyginus. Under excellent conditions, this rille resolves into a series of

Aries’ hoofprint and a series of rilles



A jumble of mountains surrounded by two lava channels creates the impression of a ram’s hoofprint. CONSOLIDATED LUNAR ATLAS/UA/LPL; INSET: NASA/GSFC/ASU

small pits. It stands out nicely at sunrise because one wall is brightly sunlit while the other remains in shadow.

The hoofprint is a short-lived feature, however. In 24 hours, the Sun’s glare renders it a mere echo of its former magnificence.

background stars of Libra comes to a halt on the 2nd, at which point it starts edging to the east.

Saturn makes little progress, however — it spends the entire month 13° northwest of Antares, the brightest star in neighboring Scorpius. Saturn shines at magnitude 0.5, approximately 75 percent brighter than Antares.

Naked eyes don’t do Saturn justice, however. You need a telescope to see the planet’s beautiful rings, a sight without equal in Earth’s sky. Even a small instrument delivers gorgeous views. At midmonth, the planet’s disk measures 17" across while the rings span 38" and tip 24° to our line of sight. The large tilt provides a detailed look at the ring system’s structure, most noticeably revealing the dark Cassini Division that separates the outer A ring from the brighter B ring.

— Continued on page 22

## METEORWATCH

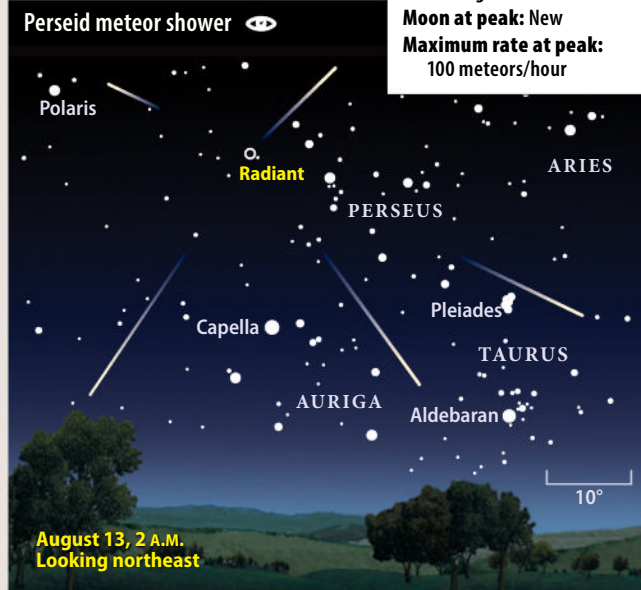
### Perseids peak with perfection

Viewing prospects couldn’t be better for the Perseid meteor shower. The peak comes the night of August 12/13, just one day before New Moon. With no Moon to interfere, observers under dark skies can expect to see up to 100 “shooting stars” per hour.

The shower’s radiant — the point from which the meteors appear to originate — lies in the constellation Perseus near its border with Cassiopeia. This region appears in the northeast by 10 P.M. local daylight time and climbs highest as dawn approaches. All else being equal, the higher the radiant, the more meteors you’ll see. Also keep an eye out for brilliant meteors known as fireballs, which the Perseids produce in relative abundance.

#### Perseid meteors

**Active Dates:** July 17–Aug. 24  
**Peak:** August 12/13  
**Moon at peak:** New  
**Maximum rate at peak:** 100 meteors/hour



This year’s best meteor shower coincides with New Moon, creating the potential for seeing up to 100 “shooting stars” per hour.

**OBSERVING HIGHLIGHT** Neptune reaches its 2015 peak August 31, when the eighth planet glows at magnitude 7.8 and appears 2.4" across through a telescope.



# STAR DOME

**How to use this map:** This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

**The all-sky map shows  
how the sky looks at:**

11 P.M. August 1  
10 P.M. August 15  
9 P.M. August 31

**Planets are shown  
at midmonth**

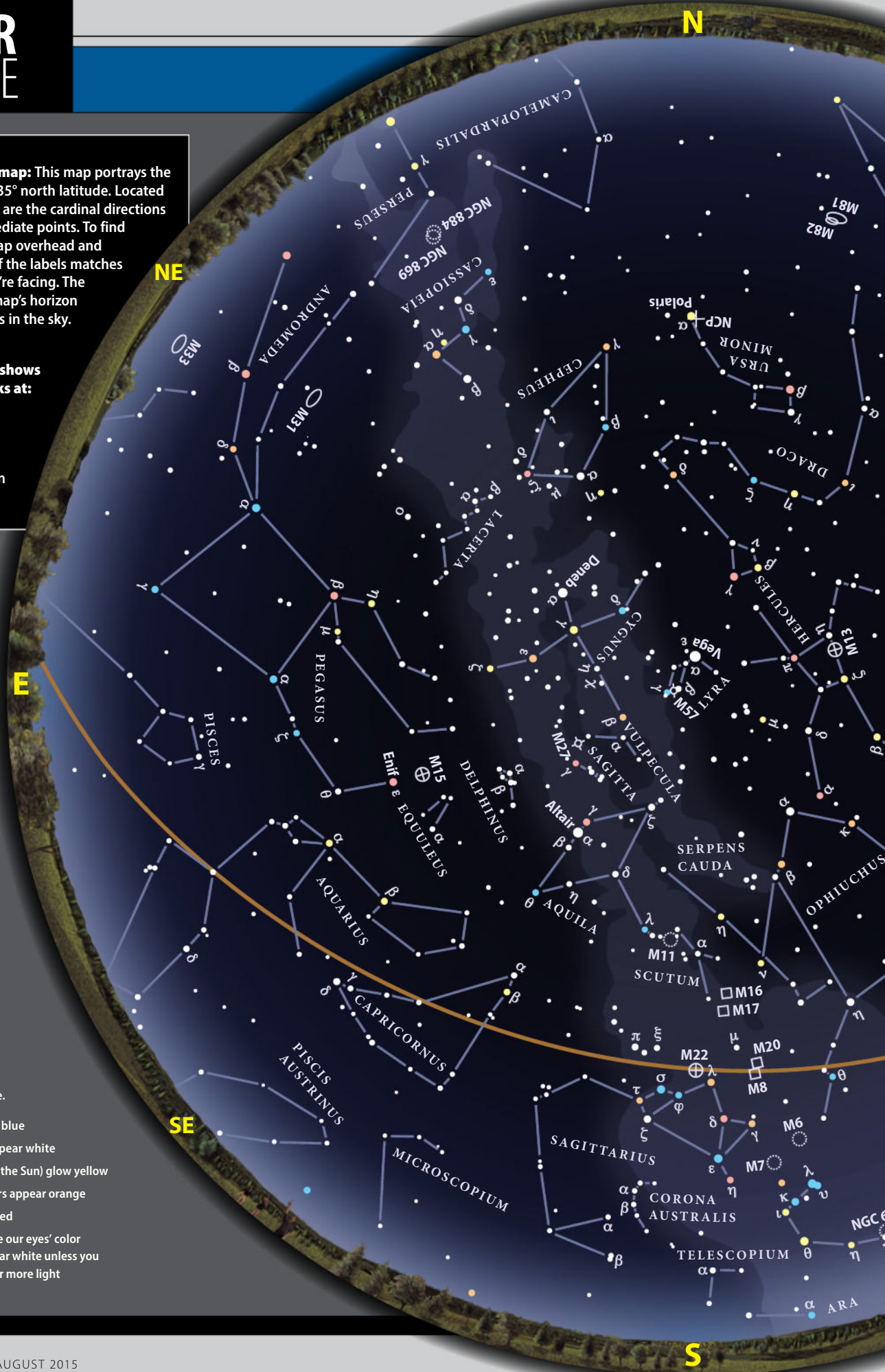
## STAR MAGNITUDES

- Sirius  
● 0.0  
● 1.0  
● 2.0  
● 3.0  
● 4.0  
● 5.0

## STAR COLORS

**A star's color depends on its surface temperature.**

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light










































# AUGUST 2015

**Note:** Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
						
						
						
						
						
						

## Calendar of events

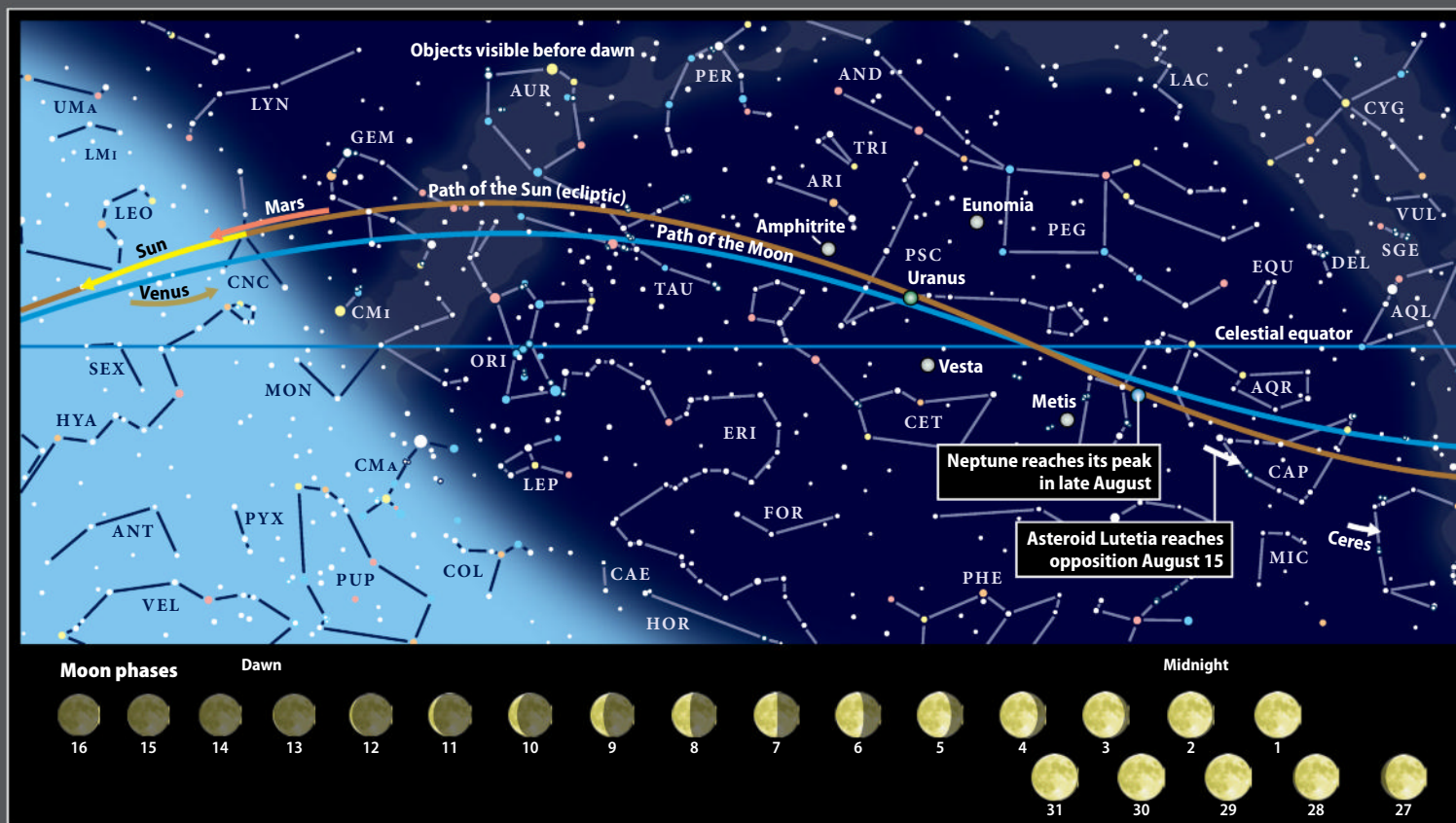
- 2** The Moon is at perigee (225,023 miles from Earth), 6:03 A.M. EDT  
The Moon passes 3° north of Neptune, 11 A.M. EDT  
Saturn is stationary, 4 P.M. EDT
- 5** The Moon passes 1.0° south of Uranus, 5 A.M. EDT  
Mercury passes 8° north of Venus, 5 A.M. EDT
- 6**  Last Quarter Moon occurs at 10:03 P.M. EDT  
Mercury passes 0.6° north of Jupiter, midnight EDT
- 7** Mercury passes 1.0° north of Regulus, 11 A.M. EDT
- 8** The Moon passes 0.7° north of Aldebaran, 8 P.M. EDT
- 10** Jupiter passes 0.4° north of Regulus, 7 P.M. EDT
- 13** The Moon passes 6° south of Mars, 1 A.M. EDT
- 13** The Perseid meteor shower peaks under Moon-free skies before dawn.
- 14**  New Moon occurs at 10:53 A.M. EDT
- 15** Asteroid Lutetia is at opposition, 10 A.M. EDT  
Venus is in inferior conjunction, 3 P.M. EDT
- 16** Asteroid Vesta is stationary, 2 A.M. EDT
- 17** The Moon is at apogee (252,182 miles from Earth), 10:33 P.M. EDT
- 22** The Moon passes 3° north of Saturn, 1 P.M. EDT  
 First Quarter Moon occurs at 3:31 P.M. EDT
- 26** Jupiter is in conjunction with the Sun, 6 P.M. EDT
- 29** Venus passes 9° south of Mars, 1 A.M. EDT  
 Full Moon occurs at 2:35 P.M. EDT  
The Moon passes 3° north of Neptune, 8 P.M. EDT
- 30** The Moon is at perigee (222,631 miles from Earth), 11:21 A.M. EDT
- 31** Neptune is at opposition, midnight EDT

See tonight's sky in Astronomy.com's

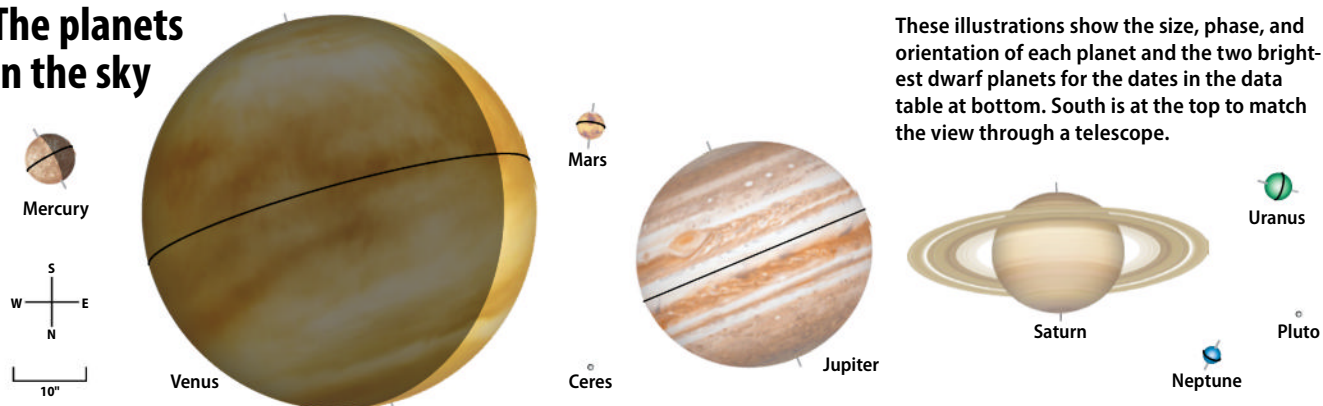
# STARDOME



BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT [www.Astronomy.com/starchart](http://www.Astronomy.com/starchart).



### The planets in the sky

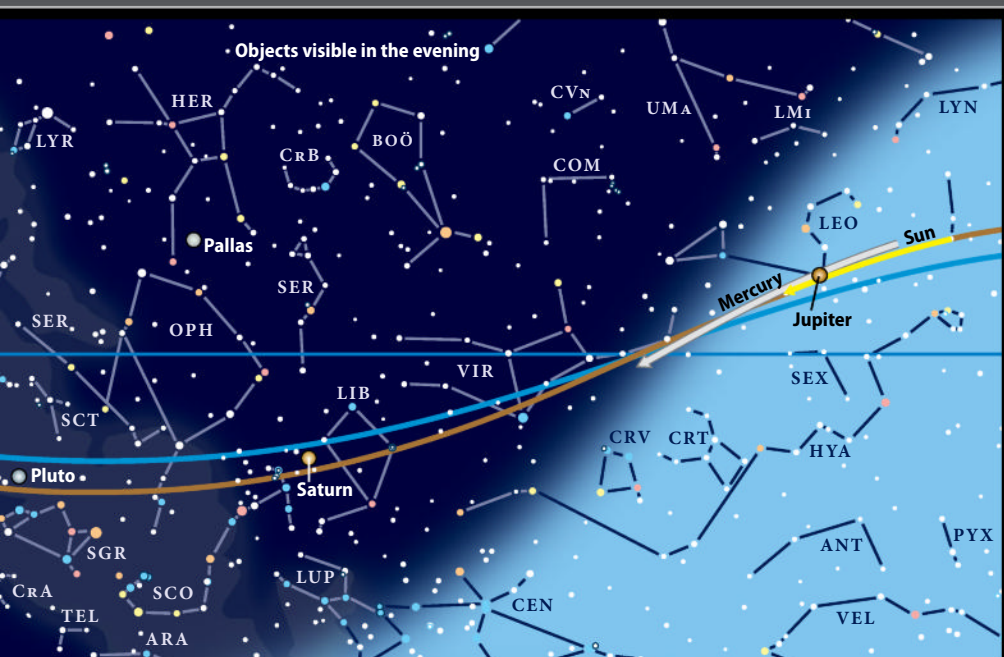


These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets for the dates in the data table at bottom. South is at the top to match the view through a telescope.

Planets	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	Aug. 31	Aug. 31	Aug. 15	Aug. 15	Aug. 1	Aug. 15	Aug. 15	Aug. 15	Aug. 15
Magnitude	0.1	-4.5	1.7	7.8	-1.7	0.5	5.8	7.8	14.1
Angular size	6.7"	52.2"	3.7"	0.7"	31.1"	16.9"	3.6"	2.4"	0.1"
Illumination	61%	8%	99%	99%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.008	0.320	2.553	2.010	6.329	9.825	19.439	28.993	32.129
Distance (AU) from Sun	0.466	0.727	1.620	2.952	5.382	9.991	19.988	29.963	32.928
Right ascension (2000.0)	12h11.0m	9h00.6m	8h25.0m	20h09.2m	10h00.2m	15h45.6m	1h15.3m	22h42.3m	18h56.3m
Declination (2000.0)	-3°05'	8°55'	20°21'	-31°34'	13°08'	-17°53'	7°15'	-9°05'	-20°53'



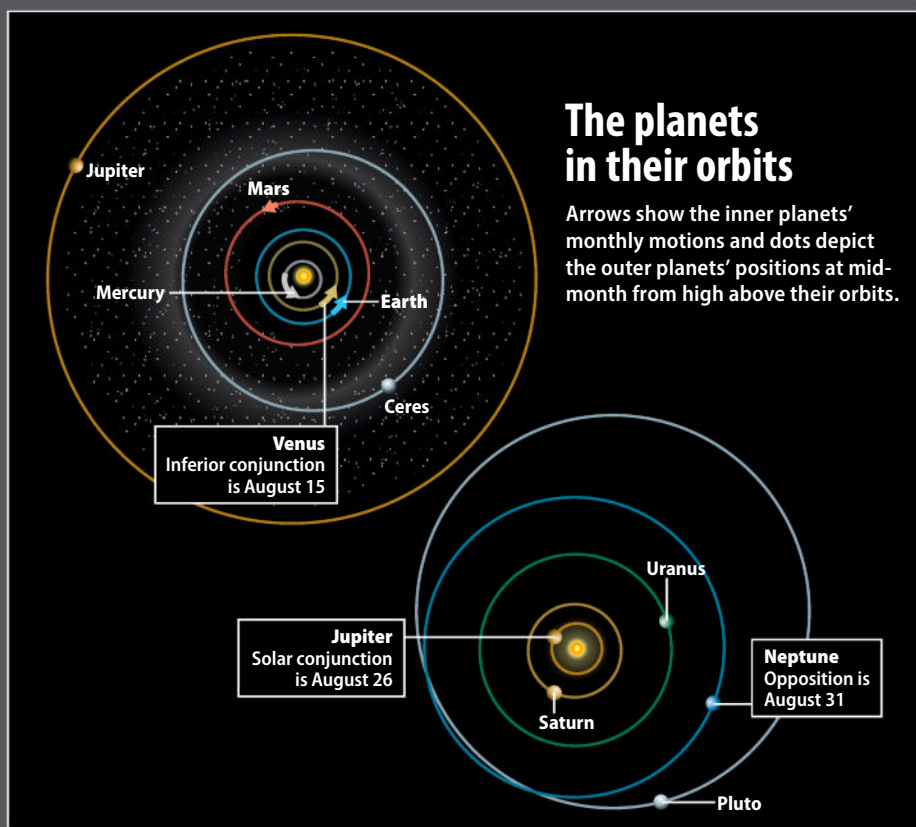
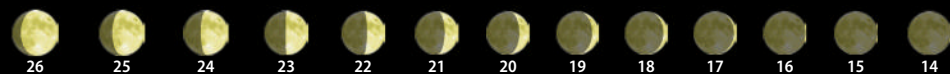
This map unfolds the entire night sky from sunset (at right) until sunrise (at left).  
Arrows and colored dots show motions and locations of solar system objects during the month.



Objects visible in the evening

Early evening

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.  
Note: Moons vary in size due to the distance from Earth and are shown at 0h Universal Time.

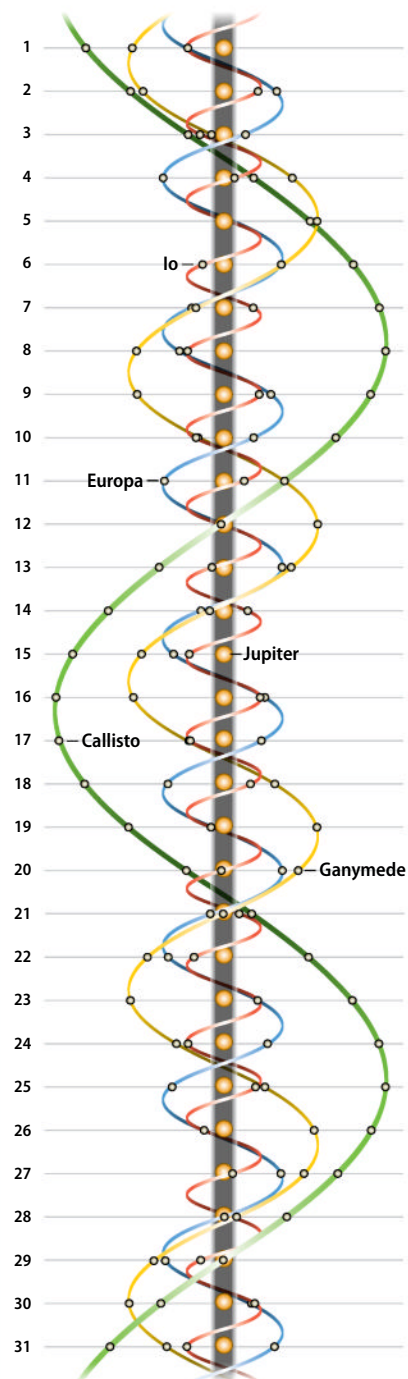
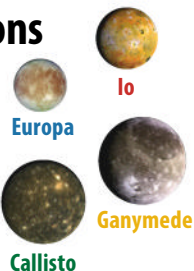


## The planets in their orbits

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at mid-month from high above their orbits.

## Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on the date shown. South is at the top to match the view through a telescope.



ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY

## WHEN TO VIEW THE PLANETS

### EVENING SKY

Mercury (west)  
Venus (west)  
Jupiter (west)  
Saturn (southwest)  
Neptune (east)

### MIDNIGHT

Saturn (southwest)  
Uranus (east)  
Neptune (southeast)

### MORNING SKY

Venus (east)  
Mars (east)  
Uranus (south)  
Neptune (southwest)

Speaking of viewing angles, Saturn reaches quadrature August 22. If you were to draw a line from the Sun to Earth and then to Saturn on this date, it would form a 90° angle. To an observer, quadrature means the shadow cast by Saturn falls as far east of the planet as possible and hides a noticeable section of the rings' far side from view. The effect makes the planet look particularly three-dimensional, and it lasts for a few weeks.

Several of Saturn's moons also show up through small telescopes. The largest, 8th-magnitude Titan, is the brightest object near the planet. The satellite appears due north of Saturn on August 7 and 23 and due south August 14 and 30.

Tethys, Dione, and Rhea glow at 10th magnitude, bright enough to appear through 4-inch scopes. They all orbit inside Titan and appear in different configurations from night to night. Distant Iapetus also shines at 10th magnitude during August's first week. It reaches greatest western elongation on the 6th, when it lies 8.3' from Saturn and its bright hemisphere faces Earth. It fades by a magnitude by the time it passes 2.1' due north of Saturn on August 25/26.

By the time August rolls around, **Pluto** should be transformed from a fuzzy blob into a world of stark landscapes and who knows what else thanks to the July 14 flyby of NASA's New

### An ice giant at its best



**Neptune comes to opposition August 31, when viewers can spot the distant world's 8th-magnitude glow among the background stars of Aquarius.**

Horizons spacecraft. The encounter undoubtedly will raise Pluto's stature and spark a desire among observers to see it with their own eyes.

To track down the 14th-magnitude point of light, you'll need an 8-inch or larger scope, a dark sky, and a detailed star chart (see p. 36). Fortunately, it lies in an area of northeastern Sagittarius occupied by a couple of bright stars. On August 1, Pluto stands 60 percent of

the way along a line joining magnitude 3.5 Xi<sup>2</sup> (ξ<sup>2</sup>) Sagittarii and its magnitude 5.1 neighbor, Xi<sup>1</sup> (ξ<sup>1</sup>) Sgr. As August progresses, the distant world moves to the west, ending the month 35' west-northwest of Xi<sup>2</sup>. To confirm a sighting, plot the star field and come back a night or two later. The object that moved is Pluto.

The other two outer planets are also on display most of

## COMETSEARCH

### Wanted: Dead or alive

Could this be the end — of Comet 141P/Machholz, that is? When Don Machholz discovered it in August 1994, he thought it was a single object. But subsequent observations showed it consisted of five pieces. The split caused the comet to flare two magnitudes brighter than astronomers had predicted.

We could be in for a nice display this year if the comet breaks apart as it nears its closest approach to the Sun on August 24. It might reach 8th magnitude, which would bring it within range of 4-inch telescopes under a dark sky.

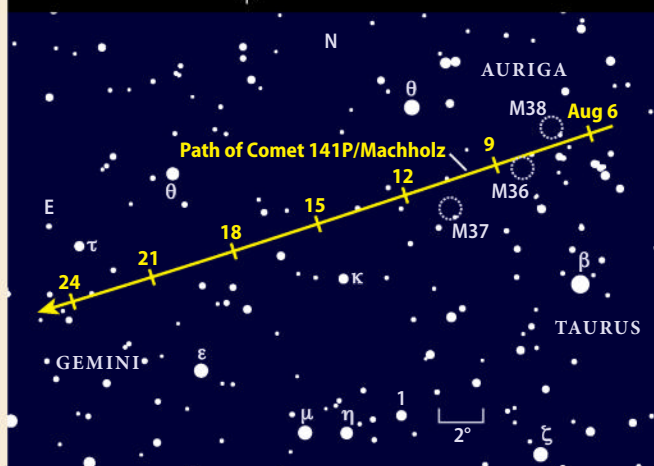
Comet Machholz is cruising through Auriga, which lies in

the northeast before dawn. On the mornings of August 7 and 8, the comet should make a nice photographic target despite competing light from a waning Moon. It then lies between the bright star clusters M36 and M38, with M37 also close by.

There's a backup in case Machholz dissolved into dust during its last pass through the inner solar system in 2010, when it was hidden behind the Sun. Comet 22P/Kopff should glow around 11th magnitude as it slides through Virgo a few degrees north of Spica.

There's also a 7th-magnitude comet for observers south of the equator. Comet Catalina (C/2013

### Comet 141P/Machholz



**Assuming the breakup of this comet is not yet complete, observers can expect to see its fuzzy glow near Auriga's brightest star clusters.**

US10) currently is heading north, passing near Alpha (α) Centauri in late August. If the comet pans

out, it should be visible to naked eyes from the rest of the world on December mornings.



## Venus and Mars are all right tonight



The predawn sky comes alive with planets in late August. Both Venus and Mars emerge from the Sun's glare to start long morning apparitions.

the night and have the distinct advantage of being easy to spot through binoculars. **Neptune** comes into view first. This ice giant world reaches peak visibility when it lies opposite the Sun in our sky August 31. It then rises at sunset, appears highest in the south around 1 A.M. local daylight time, and sets as the Sun comes up. It also shines brightest at opposition, reaching magnitude 7.8, though it is only imperceptibly dimmer the rest of the month.

To locate Neptune, first find magnitude 3.8 Lambda ( $\lambda$ ) Aquarii, which lies about 10° southeast of Aquarius' distinctive Water Jar asterism. At opposition, Neptune lies 3.4° southwest of Lambda (see the finder chart on p. 42). Don't confuse the planet with a magnitude 6.9 star located just 9' to its southwest. Use a telescope to differentiate the two. Neptune shows a 2.4"-diameter disk with a blue-gray hue, while the star appears as a mere point of light.

**Uranus** rises about 90 minutes after Neptune and climbs highest in the south around the time morning twilight begins. Uranus shines at magnitude 5.8 among the background stars of Pisces the Fish. That's bright enough to spot with naked eyes under a dark sky, but binoculars make the task

much easier. To quickly find the correct region, start with Algenib (Gamma [ $\gamma$ ] Pegasi), the 3rd-magnitude star that marks the southeastern corner of the Great Square of Pegasus. Then scan 17° southeast of Gamma to pick up magnitude 5.2 Zeta ( $\zeta$ ) Piscium.

Uranus hovers within 0.6° of Zeta throughout August, beginning the month southeast of the star and ending it a bit west of due south. When viewed through a telescope, Uranus shows a disk that measures 3.6" across and appears distinctly blue-green.

Although the predawn sky is bereft of planet activity in early August, things pick up considerably by month's end. You might catch a glimpse of **Mars** by midmonth, when the planet rises 90 minutes before the Sun and climbs 5° high an hour before sunrise. It shines at magnitude 1.7, so you'll likely need binoculars to pick it out of the twilight glow.

The Red Planet's most interesting event this month comes on the 20th when it crosses the famous Beehive star cluster (M44) in Cancer the Crab. The low altitude and competing twilight will make the pair, and M44 in particular, challenging to see even

## LOCATING ASTEROIDS

### Ceres enters the spotlight

It's amazing when you think about it: This month, observers have the opportunity to view two nondescript points of light while those dots unfold as real worlds to visiting spacecraft. Although New Horizons passed Pluto in July, data will continue streaming back well into next year. Meanwhile, the Dawn spacecraft continues to orbit and unveil asteroid 1 Ceres.

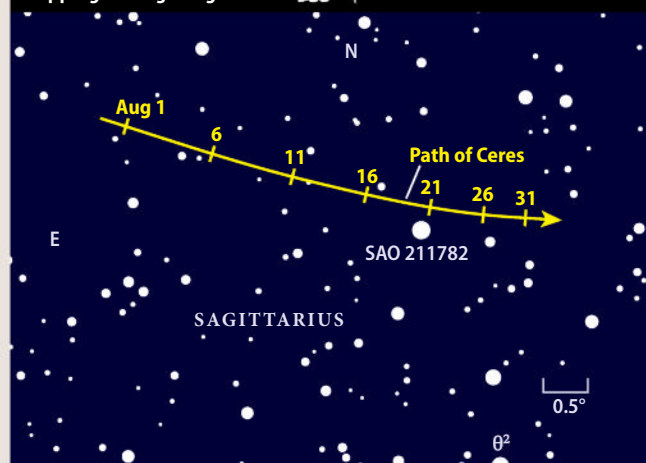
Ceres glows at 8th magnitude during August, just a touch fainter than when it reached opposition and peak visibility in July's final week. It lies among the background stars of eastern Sagittarius, 20° east of that constellation's conspicuous Teapot asterism. This region appears low in the southeast during deepening twilight and climbs highest

in the south around midnight local daylight time.

The brightest stars in this vicinity are magnitude 5.3 Theta<sup>2</sup> ( $\theta^2$ ) Sagittarii and magnitude 5.0 SAO 211782. Once you locate these two, you should be able to star-hop to the right spot using the finder chart below. The task is easiest if you look August 20 or 21 when Ceres slides 0.3° north of SAO 211782.

Or you can let Earth's spin do the work. Locate the 6th-magnitude globular star cluster M55, insert a low-power eyepiece, turn off your telescope's drive, and take a break. On August 1, Ceres will rotate into the field 41 minutes later. By month's end, you'll need to wait only 20 minutes, though you will have to nudge the scope a bit to the south.

### Slipping through Sagittarius



Although Ceres reached its peak in late July, the 8th-magnitude asteroid will be an easy target among the stars of Sagittarius during August.

with optical aid. But it's worth the attempt if you have excellent sky conditions.

Mars becomes a bit easier to see as it climbs higher by the end of August, but by then **Venus** will dominate the morning sky. After passing through inferior conjunction on the 15th, the inner planet

jumps into view during August's final week. Gleaming at magnitude -4.5, it appears conspicuous in the eastern sky even during twilight. On the 31st, you can find Mars 9° to Venus' upper left. Through a telescope, the inner world shows a giant disk 52" across and just 8 percent lit. ☾



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# Kitt Peak Observatory's

The next generation of mega telescopes promises to democratize astronomy, but aging national observatories must redefine their relevance to survive the revolution.

by Eric Betz

**H**illary Mathis helped construct one of the most unusual astronomical instruments ever conceived. She was still an undergraduate when she worked on a set of nine cartridges designed to hold circular metal plates. The plates are pockmarked with hundreds of holes, like thinly sliced aluminum tree trunks beset by demonic termites. Each hole is drilled for a specific galaxy, allowing in only the light from its target, and the cartridges must be changed with each observation on the 2.5-meter Sloan Digital Sky Survey (SDSS) telescope at Apache Point Observatory in New Mexico.

The team plugs fiber optic cables into the holes by hand to siphon each galaxy's light into a spectrograph that can decipher its redshift and deliver a precise position.

*Astronomy* heralded the historic sky survey's start in our October 1998 issue, saying it would amass 12 terabytes of publicly available data over the initial five years, which would rival all the content stored by the Library of Congress at the time. From first light to the SDSS III survey completed last year, this revolutionary project has been responsible for the most detailed 3-D maps of the universe.

And beyond the project's enormous success, it's also proved to be a harbinger of what's to come.

But SDSS will soon seem like pushing punch cards into computers. Mathis now heads the operations group for Kitt Peak National Observatory's 4-meter Mayall Telescope south of Tucson, Arizona, where she oversees instrument changes. And a truly incredible device is on its way. In mere months after its first light, projected for 2018, the new \$70 million Dark Energy Spectroscopic Instrument (DESI) will surpass the monumental success of its predecessor.

When complete, it will allow astronomers to image galaxies up to 10 billion light-years away thanks to 5,000 fiber optic cables.

Instead of a team drilling plates and hand-positioning cables, the fiber optics can be repositioned via actuators in just 40 seconds.

"This instrument is so powerful that in its first night of observations it will record more data than anyone else has at that kind of cosmological depth," says DESI Project Director Michael Levi of the Lawrence Berkeley National Laboratory.

But this seemingly massive new survey is actually small in comparison to what's on the horizon for astronomy. Big collaborations of scientists are set to consume even bigger budgets, forcing organizations overseeing older telescopes to make difficult decisions. Within a decade, five separate billion-dollar mega telescopes will open in Hawaii and across Chile, Africa, and Australia.

**Eric Betz** is an associate editor of *Astronomy*. He is on Twitter @ericbetz.



# second chance at life



The ivory tower housing Kitt Peak National Observatory's 4-meter Mayall Telescope stands tall over the Arizona desert, as it has for nearly five decades.

MARIAH BAKER

Astronomers typically get a few nights each year on a large telescope. The 8.4-meter Large Synoptic Survey Telescope (LSST) in Chile will view the entire visible sky twice a week for a decade. On any given night, it will collect more data than SDSS did in its first five years. That data will be immediately available online to anyone.

"We as astronomers are not used to working with machines like this," LSST scientist Mario Juric of the University of Washington told an audience of SETI Institute astronomers last year. "We were traditionally a really, really data-starved science. It used to be there were many theories, but no way to disprove them. If you had the telescope, that was the key differentiator for making it or not."

## The democratization of astronomy

A century ago, wealthy and generous individuals helped form prestigious institutions that controlled the world's best telescopes. From Lick Observatory to Lowell, and from Yerkes to Palomar, astronomers with rich benefactors most often were the ones who made discoveries.

But in 1955, a panel of astronomers recommended constructing telescopes owned by taxpayers and open to all, regardless of affiliation. Like the national parks long before, this American idea allowed equal access. The National Science Foundation (NSF) called it their "open skies" policy. Time was distributed on the peer-reviewed worthiness of proposals.





Construction workers build Kitt Peak National Observatory's 4-meter Mayall Telescope in June 1969.

NOAO/AURA/NSF

Kitt Peak became the birthplace of the National Optical Astronomy Observatory (NOAO), and the 4-meter Mayall Telescope was its flagship. Construction began in 1968, the same year Apollo astronauts first circled the Moon. The idea eventually spread to include a network of American-owned and NSF-supported optical, radio, and solar telescopes across the country. As a result, the United States pushed to the forefront of astronomy.

Fast-forward to present day, and Kitt Peak remains a workhorse for the American astronomer. With its suite of telescopes, the observatory now provides a sum of 800 nights of research each year, with a little less than half of that happening on the Mayall. Still, the newest telescope on the mountain, the 3.5-meter Wisconsin-Indiana-Yale-NOAO (WIYN), is more than two decades old.

The NSF now supports more than a dozen telescopes, with plans to spend billions of dollars for new instruments at some of the world's darkest sites. Veteran astronomers expect the most ambitious of these projects, LSST, will bring true transformation to the field, similar to that wrought by the Mayall some 50 years ago.

DESI is an order of magnitude improvement over the Sloan survey, but the Large Synoptic Survey Telescope will be like SDSS on steroids. It will record an epic 10-year movie of the entire southern sky out to an incredibly faint magnitude 24.5 — some 16 million times fainter than the naked eye can see. There will be no proposals for use, no competition for time. And this torrent of the cosmos will be unleashed online where absolutely anyone can access it as soon as LSST sees first light in 2022.

"When you think of a telescope, you typically think of something that's on a mountain, and then an astronomer goes there and sits at a computer and does something, maybe they'll look at

For many astronomers, big data will end the already diminished need to actually visit a telescope.



HALE OBSERVATORIES, COURTESY AIP EMILIO SEGRE VISUAL ARCHIVES

The stereotype of astronomers, like Edwin Hubble, as lone stargazers peering through an eyepiece hasn't been accurate since electronic detectors eliminated the need to look through a telescope. But the next generation of telescopes will eliminate the need to even visit a such an instrument.

their favorite object and go home," says Juric. "This is not the way this telescope is going to operate. It's practically a robot that sits on top of a mountain, and it does its thing."

Engineers expect 28 billion alerts over the course of LSST's life, letting astronomers know in real time when something changes from one image to the next, giving new hope for finding supernovae, comets, asteroids, galaxies, and who knows what else.

The scientific bounty will be unprecedented in astronomy — like when biologists unlocked the genome. The results also will create a new data challenge. For many astronomers, big data will end the already diminished need to actually visit a telescope.

## The portfolio review

To pay for new telescopes like LSST, the NSF has decided to let go of some of the old. In 2012, a portfolio review written by astronomers recommended the agency stop funding six telescopes, four of which sit atop Kitt Peak.

The group's report suggested ending NSF funding for Kitt Peak's Mayall, WIYN, and 2.1-meter telescope, plus the McMath-Pierce Solar Telescope, run by the National Solar Observatory (NSO). The National Radio Astronomy Observatory (NRAO) operates the other two facilities recommended for closure: the Green Bank Telescope (GBT) in West Virginia, a radio dish that's the world's largest single steerable telescope; and the Very Long Baseline Array, a network of 10 radio dishes spread across the country. Combined, the facilities cost \$20 million to run each year, or about 10 percent of the NSF's annual astronomy budget.

The report recommended spending that money on new projects like LSST and handing off the old instruments to other institutions. But that hasn't been an easy task because the old scopes are still producing new science and universities who might be interested also are pressed for cash.

The report writers said the GBT, the newest of the NSF facilities on the chopping block, was exceptional in its resolution, but its science goals could also be done on other instruments, sometimes with better results. The radio telescope costs around





Scientists are after new funding sources for the National Radio Astronomy Observatory's Green Bank Telescope in West Virginia, which is targeted to lose its current financial backing by 2017. So far, the National Science Foundation hasn't moved to divest. NRAO/AURA



Kitt Peak's McMath-Pierce Solar Telescope, the largest such instrument in the world, will close by 2017 unless another group agrees to take over. NOAO/AURA/NSF

\$8 million per year to operate. That site has rallied support from the state's congressional leaders, who helped secure \$1 million a year for West Virginia University to take a share of GBT time. Scientists also sent rebuttal letters touting the GBT's unique ability to study pulsars, which are being put to use by an international collaboration using NSF funds to search for gravity waves.

The report also concluded that Kitt Peak's 1.6-meter McMath-Pierce Solar Telescope, dedicated in 1962 and currently the largest solar telescope in existence, should lose funding "as soon as possible." The facility has since been reduced to a \$200,000 yearly budget, the minimal amount to maintain operations, with just one part-time staff operator.

"The telescope is an older facility, but in the past decade, we've averaged about 12 papers per year," says Matt Penn, an NSO associate astronomer. "If you calculate the price per paper, we're quite efficient."

Even the diminished funding will zero out by 2017, and so far no one has stepped up with funds to continue observing. Penn is hoping to find an organization or collaboration, maybe

a collection of amateurs — really anyone — that can take over the facility. As it is, observing astronomers regularly run the telescope for themselves, and when something goes wrong, the NOAO staff often comes over to help out their sibling agency. If any of the instruments break, there's no cash to cover a fix.

And McMath isn't alone in its rapid shift to an uncertain retirement. The Big Bear Solar Observatory outside Los Angeles, which saw first light on updated instruments in 2010, and the Dunn Solar Telescope in New Mexico also are slated to close in 2017. The NSF is unloading its Sun-watching scopes in preparation for a new behemoth, the \$344 million Daniel K. Inouye Solar Telescope (DKIST) in Hawaii.

This 4-meter is giant for a solar scope and employs adaptive optics, a technological tool typically reserved for astronomers trying to see through Earth's turbulent atmosphere to far-off suns. Instead, the DKIST will reveal our nearest star in unprecedented detail.

Astronomers hope close-up views of solar surface features will unravel the mystery of our Sun's magnetism and lead to a new understanding of our active star.

But losing all three current major solar telescopes two years before the DKIST opens will leave a gap in astronomers' ability to watch the Sun in high resolution and study solar storms. Spacecraft can see the Sun in multiple wavelengths without the filter of Earth's atmosphere, but they have significantly worse views of our star than their much larger earthly counterparts. And because astronomers also regularly use the McMath at night to observe bright objects like the Moon and Mercury, other unique abilities will disappear without its long eye.

## Saved by steel

Overall, Kitt Peak actually has had an easier time repositioning itself than most. Instead of closing or reducing operations, negotiations led to the mountain's two main telescopes getting major overhauls and new alliances of operators that will prime them to make pioneering discoveries.

"[LSST is] practically a robot that sits on top of a mountain, and it does its thing."

— Mario Juric



The National Science Foundation is putting up more than \$1 billion for the Large Synoptic Survey Telescope, which will record a movie of the entire southern sky every three days for a decade. TODD MASON, MASON PRODUCTIONS/LSST CORP.



Engineers will remove the Mayall Telescope's top half and replace it with an elaborate system of lenses and fiber optic cables made to hunt dark energy. The 0.5-million-pound (225,000 kilograms) steel mount — designed in the late 1960s — makes it an ideal place for the large instrument. NOAO/AURA/NSF

**"If we want to continue doing frontline science, we have to start doing project science."**

— Lori Allen

"Things looked a little dire a few years ago when the NSF portfolio review came out and recommended divestment at Kitt Peak," says Observatory Director Lori Allen, who took over in 2013. "But through the diligent work of the NSF and the other federal agencies working closely with us, I think we've designed a future for both of these 4-meter telescopes."

In addition to the Mayall's makeover with DESI, the WIYN will be reborn as a high-tech exoplanet research instrument. The NSF will continue supporting the partnership with new funds from NASA to help answer another defining question of our age: Are we alone? The space agency will pay for an extreme precision radial velocity spectrometer called NN-EXPLORE, which will be put to use studying exoplanets around nearby stars. WIYN also will make follow-up observations of alien worlds seen by NASA's Transiting Exoplanet Survey Satellite, set for launch in 2018.

Kitt Peak's 2.1-meter telescope is in the process of being handed off to a consortium of universities for their own research. All the projects still need Congress to approve, but that support looks likely.

"We've always been an open-access observatory and rightly so because we were funded entirely by the NSF for that purpose," Allen says. "Now we're in a situation where the NSF can no longer fund us at that level. If we want to continue doing frontline science, we have to start doing project science."

For the Mayall, its antiquated frame actually proved to be its saving grace. With minimal modification, the telescope can support an instrument that weighs as much as four Toyota Land Cruisers.

"The [portfolio review] timing was fabulous because the DESI instrument, it's big," Levi says. "It's the size and weight of a school bus — 10,000 kilograms [22,000 pounds]. It's heavy. We were actually looking for an older telescope, and the Mayall happens to be perfect because it's built of so much steel."

The telescope structure weighs half a million pounds (225,000kg) — two times heavier than the infamous Hughes H-4 Hercules airplane, or "Spruce Goose," and nearly as much as the world's largest current passenger aircraft, the Airbus A380. To make way for DESI, engineers must remove the Mayall's entire top end. "This thing is just massively over-engineered," Levi says. "It's insanely well built."

Another benefit of the Mayall is that it allows this new dark energy survey an unrivaled 8-square-degree field of view. DESI will tear through the night sky like a cosmic cookie cutter, stamping out circles 40 times bigger than the Full Moon with each of its estimated 10,000 observations.

## The dark energy map

DESI traces its origins to an SDSS project that examined galaxy structure in the early universe through the Baryon Oscillation Spectroscopic Survey (BOSS). Baryons make up most of our universe's matter in heavy particles like protons and neutrons. BOSS showed that this matter made sound waves and left imprints on the early universe, like pebbles tossed into a pond, creating fluctuations in the cosmic microwave background as the cosmos cooled enough for matter to form. These early fluctuations are called baryon acoustic oscillations, and they led to uniform voids between galaxies.

Astronomers use the oscillations as a cosmic ruler to measure the 3-D positions of objects billions of light-years away.

Whereas BOSS could gather 8,000 objects per night, DESI will knock off 1.5 million. When the survey is complete, it will pinpoint the locations of some 25 million galaxies and quasars — active galactic cores — to produce the most comprehensive picture of our universe ever.

The project is a nod to the big data future of astronomy, as well as what's possible for aging observatories looking to redefine their relevance in light of new technology.

## 10 TELESCOPES TARGETED TO LOSE FUNDING

NOAO 2.1-meter telescope	Arizona
Mayall 4-meter telescope	Arizona
WIYN 3.5-meter telescope	Arizona
McMath-Pierce Solar Telescope	Arizona
SOAR 4.1-meter telescope	Chile
NSO Integrated Synoptic Program	Multiple countries
Dunn Solar Telescope	New Mexico
Very Long Baseline Array	Spread across U.S.
Green Bank Telescope	West Virginia
Arecibo Observatory	Puerto Rico

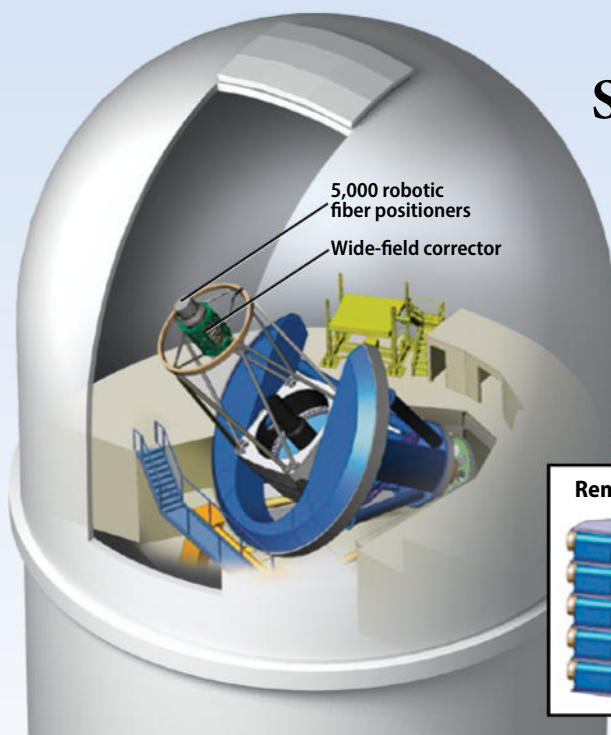


# Dark Energy Spectroscopic Instrument

The new Dark Energy Spectroscopic Instrument will place 5,000 steerable fiber optic cables atop the 4-meter Mayall Telescope, transforming it from a half-century-old workhorse into a modern robot. ASTRONOMY: ROEN KELLY, AFTER LAWRENCE BERKELEY NATIONAL LABORATORY



Technicians must drill a hole in Sloan Digital Sky Survey fiber optic cable plug plates for each individual galaxy they observe. The Dark Energy Spectroscopic Instrument does away with this labor-intensive process thanks to steerable fiber optic cables. SDSS-III



## Remote fiber-fed spectrometers



But when the Mayall is reborn in 2018, it will cease to be an open skies instrument. DESI includes 178 senior scientists from around the world, as well as their postdocs and students. This collaboration will get the first look at data before it's released. Pending continued congressional approval, the Department of Energy will foot most of the bill, with additional support from the Gordon and Betty Moore Foundation and the Heising-Simons Foundation.

"These large statistical surveys require ferocious quantities of computational power and databases and huge, long-running jobs that are not accessible to an individual," Levi says. "One person couldn't do this experiment. One person couldn't take the data and analyze it. Ten people couldn't. So now what do you do?"

Tod Lauer has been at the forefront of this culture change. The NOAO astronomer remembers pulling tables out of science journals as an undergraduate and plotting the points with a pencil. He went on to help adapt the first CCD cameras to telescopes, which ultimately led to surveys like SDSS. And while he was still a young scientist, he submitted the first paper using data from the Hubble Space Telescope. He still works with Hubble and several large surveys today, including NOAO's existing Dark Energy Survey on the Mayall's twin telescope in Chile.

Lauer says computer skills like learning to visualize data sets and employ machine learning are more important than ever for astronomers. He recently organized a workshop in Tucson called "Tools for Astronomical Big Data" and was shocked when 130 people showed up.

"We're looking ahead to these tremendously large surveys like LSST, so we can see what's on the horizon, but with our dark energy survey, we've got the problems in front of us right now," Lauer says. "We need to ride these waves and get the community ready for the next big things."

DESI will  
tear through the  
night sky like a cosmic  
cookie cutter, stamping  
out circles 40 times  
bigger than the  
Full Moon.



Star trails circle the dome of the 4-meter Mayall Telescope, which will house the Dark Energy Spectroscopic Instrument by 2018 if Congress approves final funding. P. MARENFELD & NOAO/AURA/NSF

Allen, Kitt Peak's director, thinks her observatory will be ready for those next big things.

Tucson was recently selected for the NOAO's new Data Lab, built to help astronomers utilize observations from the many surveys. And revitalization on the mountain should also carve a niche in this big data era for decades to come.

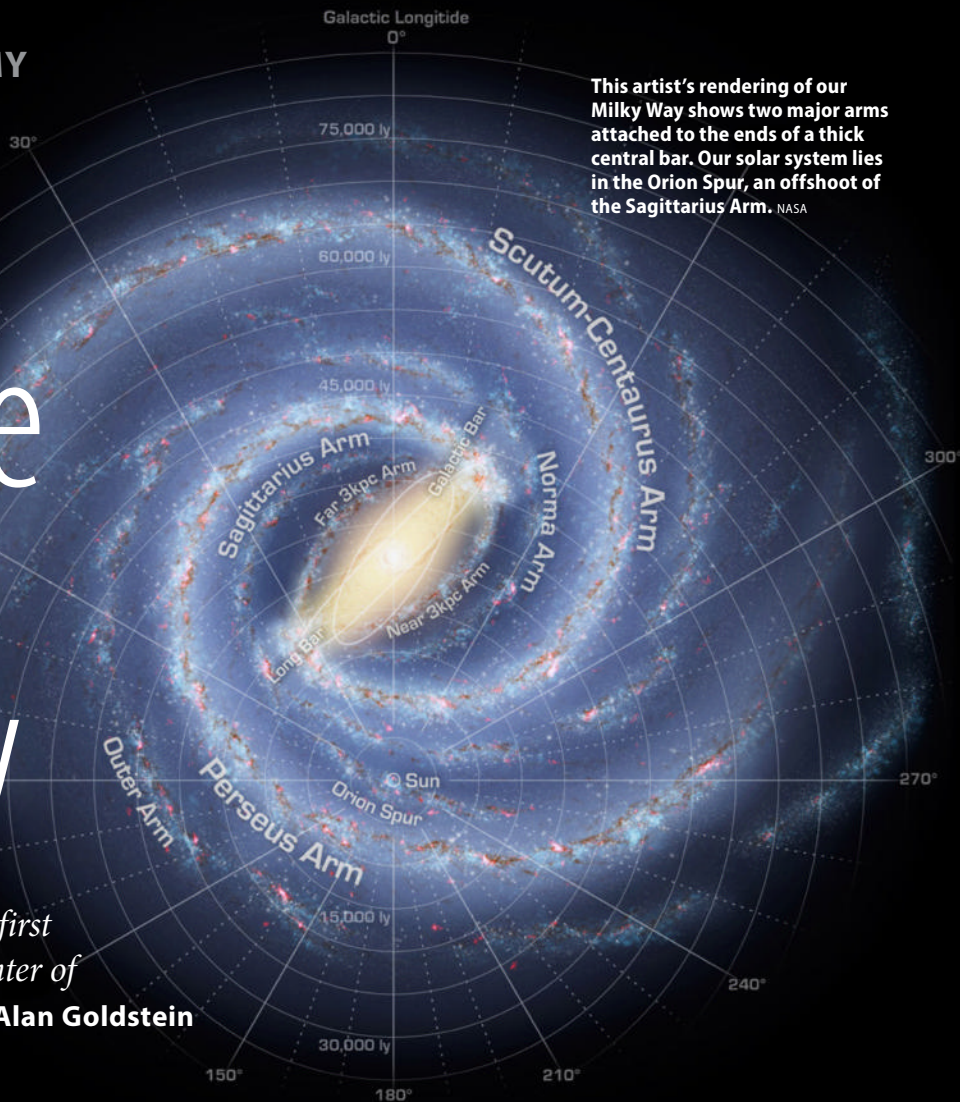
"We are undergoing a big transition right now from a 100 percent open-access facility to a more project-oriented facility," she says. "However, I'm pretty confident that a great deal of science will be enabled by these surveys and the scientific importance of Kitt Peak will continue to be significant." 🌌



FIND OUT HOW SOUND WAVES FROM THE DAWN OF TIME CAN HELP MEASURE DARK ENERGY AT [www.Astronomy.com/toc](http://www.Astronomy.com/toc).

# Finding our place in the Milky Way

*Aristarchus and Copernicus were the first to challenge Earth's position at the center of creation, but they weren't the last.* **by Alan Goldstein**



For most of human history, our species has tried to understand our world. Curiosity became science, a method of testing our explanations. Most theories that were little more than myths fell by the wayside, but some clung tenaciously for thousands of years.

One of them stated that beyond our ancestors' reach was the sky: The stars and Milky Way formed a roof above Earth. Finding our true place took millennia, the result of hard-fought battles wresting science from the grip of ignorance. And history now links relatively few astronomers to the key discoveries along the way.

## Early ideas

The first challenge encompassed the Sun, the Moon, and the planets moving among the stars. Aristarchus of Samos (310–230 B.C.) first theorized that Earth orbited the

Sun, but it wasn't until 1543 — some 18 centuries later — that Nicolas Copernicus' revolutionary calculations quantified it.

Galileo Galilei applied that knowledge to his telescopic observations of Jupiter's four satellites in 1610. He noted that they moved according to Copernicus' theory, rather than the widely held cosmological view proposed nearly two millennia earlier by Aristotle of everything in the universe orbiting Earth.

To say that not everyone was happy about the removal of humanity from the center of the universe would be a bit of an understatement, but science slowly advanced. With the widespread use (and improvement) of telescopes, the universe revealed its wonders. The Milky Way changed from a mysterious "river of milk"

to countless faint stars mixed with nebulous objects, some of which resolved into more stars. Astronomers began to understand the sky, although observations led to more questions than answers.

For nearly three more centuries, the Sun remained stubbornly where Copernicus placed it — at the center of our universe. How could it not? No techniques existed to measure our star's location in relation to the rest of the cosmos.

That changed in 1838 when German astronomer Friedrich

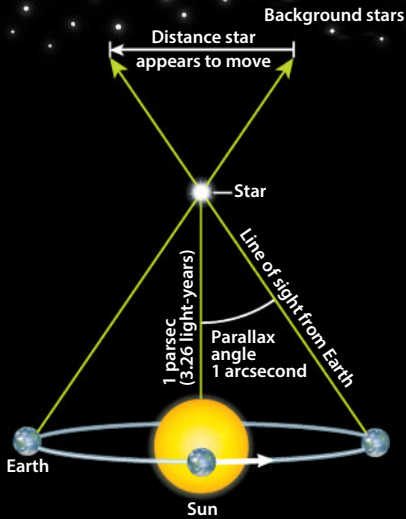
Wilhelm Bessel calculated the distance to the star 61 Cygni using stellar parallax. This technique measures the precise location of a star in relation to those in the background from opposite sides of Earth's orbit. His estimate of 10.3 light-years marked the first solid estimate

The words **galaxy** and **Milky Way** first appear in the English language in Geoffrey Chaucer's *The House of Fame* published in 1380.

**Alan Goldstein** is a longtime deep-sky observer who does most of his telescope viewing from locations near Louisville, Kentucky.



## How far is that star?



Stellar parallax allows astronomers to measure the distances to stars using geometry. A star 1 parsec (3.26 light-years) from Earth would have a parallax angle of 1 arcsecond, although no star lies that close to us.

ASTRONOMY: ROEN KELLY

of the distance to the stars, although such a direct measurement is good for only a relatively few thousand of the closest suns among the vast number much farther away.

To learn more, astronomers had to understand the nature of stars. A combination of two 19th-century inventions opened the door: the spectroscope in 1814 and photography several decades later. The discovery that the spectra of stars reveal individual chemical elements gave scientists the ability to learn their compositions.

Photography allowed astronomers to record images of stars (and spectra). By the 1880s, improved sensitivity and larger telescopes allowed them to document variable stars — those that changed in brightness over time. One type of variable star in particular was critical to opening up the universe to distance measurements.

### Cepheid (and other) variable stars

In the first decade of the 20th century, Harvard College Observatory astronomer Henrietta Swan Leavitt examined images of stars in the Small Magellanic Cloud (SMC) and found many Cepheid variables. The prototype of this class is the star Delta ( $\delta$ ) Cephei, whose variability was discovered by English amateur astronomer John Goodricke in 1784.

Leavitt observed that the longer one of these stars took to complete a cycle, the



Henrietta Swan Leavitt worked as an astronomer at Harvard College Observatory when she discovered the period-luminosity relationship of Cepheid variable stars in 1908. AAVSO

brighter its image was. Knowing the stars in the SMC were all at a similar distance, this led to her discovery of the period-luminosity relationship.

But she wasn't the one who compared them with Cepheids in the Milky Way. Danish astronomer Ejnar Hertzsprung did, and he then was able to connect the dots: The Cepheids he studied were giant, luminous stars. Hertzsprung then proclaimed that the 15th- and 16th-magnitude Cepheids in the SMC had the same luminosity as those in the Milky Way, placing the SMC much farther away.

With that wonderful revelation, the race was on to find more Cepheids and get more distances for objects in the universe. For astronomers 100 years ago, this was cutting-edge research. No one knew exactly how far celestial objects were beyond the then maximum distance for which parallax was accurate, about 300 light-years at the time.



One early belief about the Milky Way was that it was the breast milk of Hera, queen of the Greek gods, spilled across the sky when she wrenched Herakles away from her bosom. He was not her son, but Zeus had placed him there while she was asleep so he would develop godlike qualities. It wasn't until 1610 that Galileo telescopically observed the true stellar nature of the Milky Way. MIGUEL CLARO

## FINDING OURSELVES

**250 B.C.** — Aristarchus of Samos presents the first known model of the universe where Earth is not at the center.

**1514** — Nicolas Copernicus writes *Commentariolus*, an early outline of his heliocentric theory, for his friends.

**1540** — Georg Joachim Rheticus publishes *Narratio Prima*, the first printed version of Copernicus' theory.

**1543** — Copernicus' work *De revolutionibus orbium coelestium* ("On the Revolutions of the Heavenly Spheres") appears.

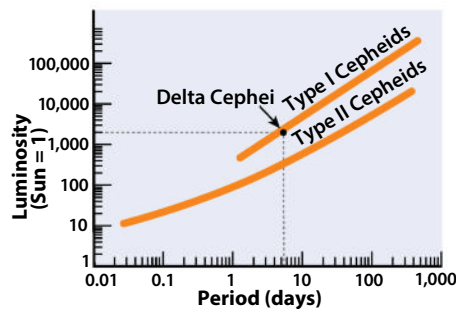
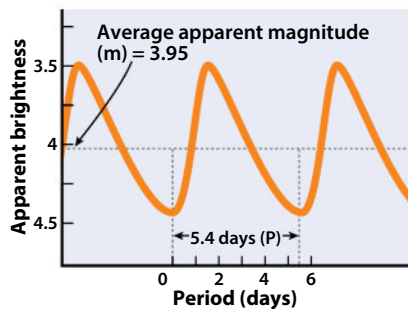
**1608** — Hans Lipperhey invents the telescope.

**1755** — Immanuel Kant theorizes the Milky Way is a large disk of stars that condensed from a rotating gas cloud.

**1784** — John Goodricke discovers the variability of the star Delta ( $\delta$ ) Cephei.

**1785** — William Herschel maps out the Milky Way's shape and places the Sun at the center of a flattened disk of stars.

# How Cepheids reveal distance



Cepheid variable stars have periods related to their brightnesses, allowing astronomers to calculate their distances accurately. Delta Cephei (above), the prototype star, varies in brightness every 5.4 days. It belongs to the initial class (Type I) of Cepheids astronomers discovered. Later, researchers found a second class (Type II), which allowed them to use fainter stars. ASTRONOMY: KELLIE JAEGER

Another Harvard astronomer, Solon I. Bailey, studied Cepheid-like variables called “cluster variables.” These were RR Lyrae stars (named for their prototype in the constellation Lyra the Harp), which observers mainly found in globular clusters. Astronomers at the time didn’t understand the differences between Cepheids and RR Lyrae stars, but they had similar period-luminosity relationships.

We now know that most Cepheids lie in the galactic plane and are up to 100,000 times more luminous than the Sun. Their variability ranges from days to months. They are yellow supergiants whose surface temperatures range from slightly hotter to slightly cooler than that of our Sun. RR Lyrae stars are older, more common in (though not exclusive to) globular clusters, and “only” 40 to 50 times more luminous than the Sun.

## Using the relationship

American astronomer Harlow Shapley worked at Princeton University, where he studied Cepheid and RR Lyrae variables from 1916 to 1919. He investigated stars in the SMC and globular clusters with the 1.5- and 2.5-meter telescopes at Mount Wilson Observatory in California.

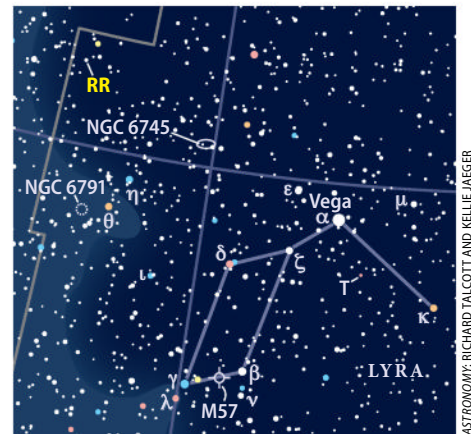
Observing variables in a large number of globular clusters in the region of the sky surrounding the dense part of the Milky Way in Sagittarius, he was able to calculate the distance of each cluster. Shapley had to assume that the nature of the stars was essentially identical in every globular cluster. While there were errors in his research due to insufficient data, they weren’t enough to detract from his conclusions.

What he found enabled him to create a three-dimensional map that revealed globulars “hovered” around a particular region that Shapley realized was our galaxy’s core. They definitely did not surround our solar neighborhood. In fact, we were not anywhere close to the center of the Milky Way.

Shapley’s estimates were off by a factor of two because of the unknown differences of the luminosities of the two types of variables. Astronomers found the correct interpretation in 1930. Still, his research moved us from the center of the Milky Way to one of its suburbs. The significance is similar to Copernicus and heliocentrism, but without the controversy. Today, the accepted distance of the Sun from the center of the galaxy is 27,200 light-years.

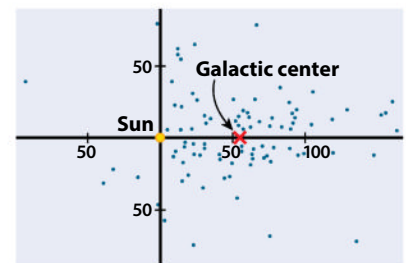
## What does the Milky Way look like?

Edwin Hubble (working with Milton Humason) pushed back the edges of the cosmos with his interpretation of the



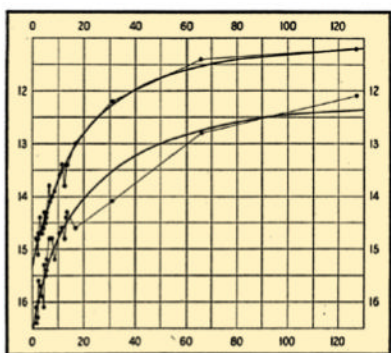
RR Lyrae is the prototype of another type of variable star whose periods and luminosities show a relationship. This star’s brightness changes from 7th to 8th magnitude and back, so you can observe it even through binoculars.

## Off-center Sun



Starting in 1916, Harlow Shapley acquired data to allow astronomers to create this 2-D plot of the distribution of our galaxy’s globular clusters relative to the Sun’s position. It shows they orbit a point far from the Sun, which Shapley proved is not in the center of the Milky Way. ASTRONOMY: KELLIE JAEGER

## A definite link



In 1912, Henrietta Swan Leavitt made these plots, which show the maximum (upper data) and minimum magnitudes and periods of 25 Cepheid variable stars in the Small Magellanic Cloud.

redshift (a feature in a galaxy’s spectrum that shows it’s moving away from us) in the spectra of “spiral nebulae.” Once this was known, the Milky Way became one of millions of galaxies in space. Hubble and Shapley are among the best-known astronomers of the 20th century because they forged human understanding of our place in the universe — but what about the structure of our galaxy?

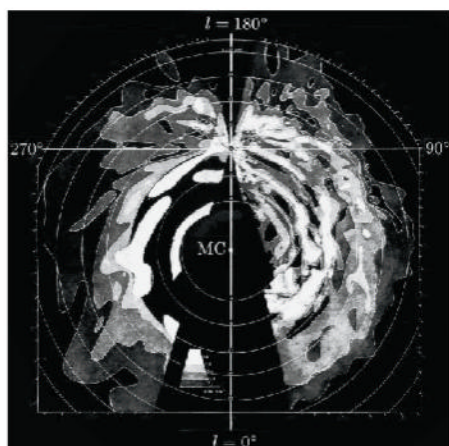
In 1951, Dutch astronomers Jan Oort and Hendrik van de Hulst published a map of the distribution of neutral hydrogen from data they obtained with a radio telescope tuned to a wavelength of 21 centimeters. This wavelength penetrates dust and gas, revealing a complicated spiral structure — the same one astronomers observed in distant spiral galaxies.

The Milky Way’s flattened shape was obvious. Its characteristics seemed to resemble other spiral galaxies, but astronomers didn’t know its structure until the





In the 1950s, astronomers at Yerkes Observatory mapped the brightest, hottest stars — O and B types like the ones shown in this image — thus creating a map of the Sun's neighborhood. ESO/T. PREIBISCH



MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY, 1958, VOL. 18

Radio waves penetrate our galaxy's dust better than visible light, so using them allows astronomers to map spiral arms farther from Earth than they can with visible stars. This map, created in 1951, uses neutral hydrogen emission at a wavelength of 21 centimeters to plot gas clouds distributed through the Milky Way's spiral arms.

early 1950s. William W. Morgan and others at Yerkes Observatory studied O and B stars (the most luminous) and traced the Orion, Perseus, and Sagittarius arms of our galaxy. The Orion Arm is where the Sun lies. The Sagittarius Arm is closer to the galactic center than we are, while the Perseus Arm is farther out. But most of the galaxy still appeared darkened by abundant clouds of dust and gas that blocked visible-light observations.

Successive investigations since the first radio maps have revealed the modern view of the Milky Way. Researchers showed that the Orion Arm is merely a spur off the Carina-Sagittarius Arm. Inward from that spiral arm is the Crux-Scutum Arm, the Norma Arm, and the Far 3kpc Arm that wraps off our galaxy's central hub. Beyond the Perseus Arm is another one simply



TOM AND GAIL HAYNES/ADAM BLOCK/NOAO/AURA/NSF

Many astronomers think spiral galaxy NGC 3953 in the constellation Ursa Major the Great Bear most resembles our Milky Way.

called the Outer Arm. And because the galactic center is so dense, it blocks observations of the arms on the opposite side.

Recent investigations have shown that the Milky Way's central hub is not round, but rather bar-shaped, though not as extreme as the archetype barred spiral galaxy NGC 1300. Still, debate exists. Some astronomers consider it a true barred spiral, while others consider the overall structure to be closer to M83 (the closest and brightest barred spiral) or the multi-armed NGC 3953. Unfortunately, only astronomers outside our galaxy have a complete picture.

## See for yourself

We have a greater understanding of the universe than at any other time in human history. Unfortunately for most of us, light pollution dims the stars that meant so much to establishing our position among them.

If you get a chance, head out to the countryside, observe the same milky circle as the ancient Greeks, and reflect on what your ancestors thought millennia ago. As you do, think about your place in the Milky Way. ☾

**1814** — Joseph von Fraunhofer invents the spectroscope, which enables astronomers to study the chemistry and motions of celestial objects.

**1838** — Friedrich Wilhelm Bessel uses stellar parallax to calculate the distance to 61 Cygni.

**1890** — Jacobus Kapteyn discovers U Leporis, the first RR Lyrae-type variable star.

**1901** — Williamina Fleming discovers RR Lyrae.

**1908** — Henrietta Swan Leavitt discovers a relationship between the periods and luminosities of Cepheid variables in the Small Magellanic Cloud.

**1914** — Harlow Shapley begins a six-year study of globular cluster distances, eventually concluding that the Sun does not lie at the center of the Milky Way.

**1924** — Edwin Hubble estimates the distances to Cepheid variables in the Andromeda Galaxy (M31), proving that system lies far beyond the boundaries of the Milky Way.

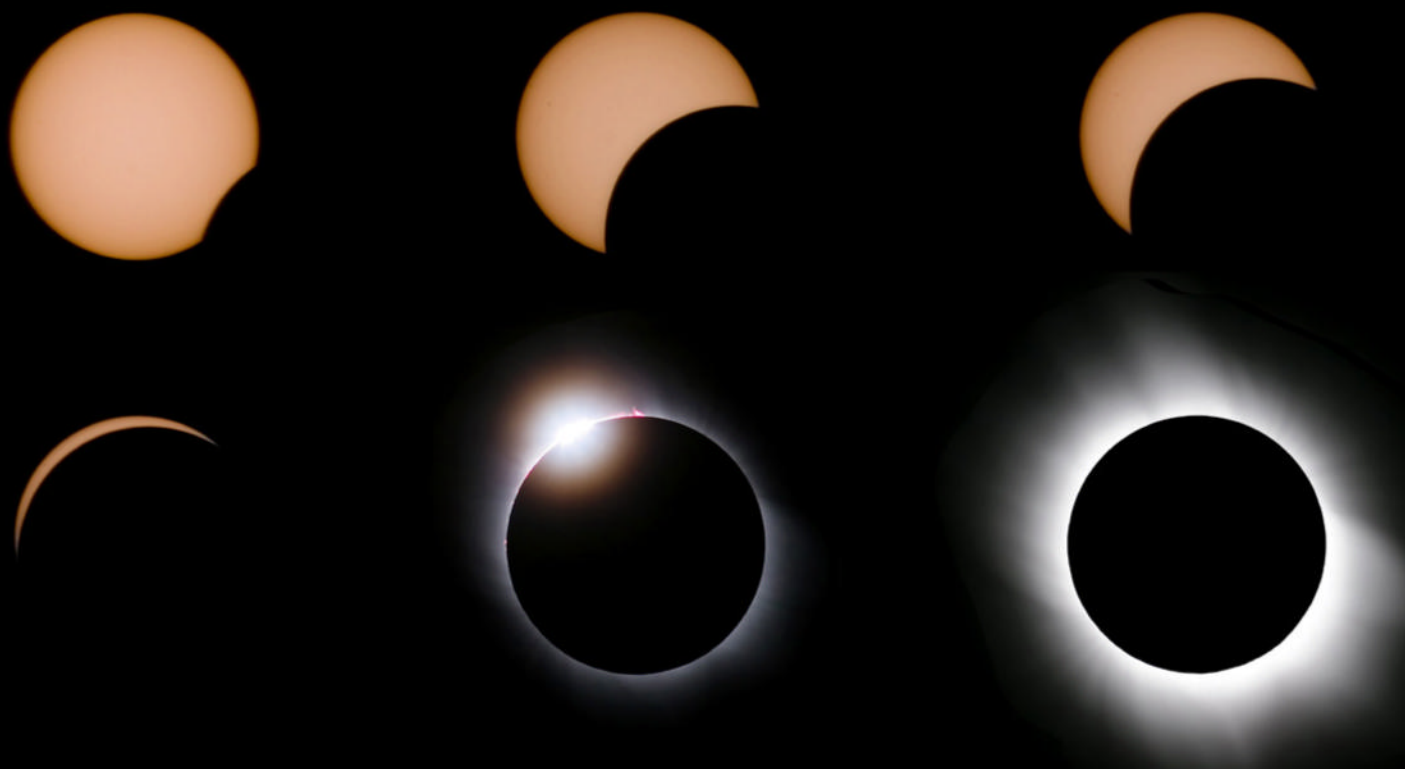
**1951** — William W. Morgan uses optical observations of bright O and B stars to map the spiral arms of the Milky Way.

**1954** — Jan Oort and Hendrik van de Hulst study 21-centimeter radio emission to trace the structure of the Milky Way.

**1989** — The Cosmic Background Explorer is launched and provides evidence that our galaxy is a barred spiral.

**2005** — The GLIMPSE program conducted by the Spitzer Space Telescope confirms the presence of the Milky Way's central bar.

**Present** — Astronomers' best measurement of the distance of our solar system from the center of the Milky Way is 27,200 light-years.



# Witness TOTALITY from INDONESIA

*A spectacular adventure awaits those who tour Bali and see the March 9, 2016, total solar eclipse. by Michael E. Bakich*

**N**ature's greatest spectacle — a total eclipse of the Sun — once again will take place as the Moon traces out a narrow path of darkness along Earth's surface. On March 9, 2016, people from across the world will travel to our planet's equatorial zone to stand in our natural satellite's dark inner shadow. For our readers wanting to view it, a long trip is in store.

Indonesia is the place to be, and for that reason, most tour groups headed to this

eclipse will spend the majority of their time on the tropical paradise of Bali.

## Touring Bali

Bali, sometimes called "Island of Gods" or "Island of Peace," is Indonesia's largest tourist destination. Each year, more than 3 million foreign visitors explore the island, mostly from Australia and China. Approximately 80 percent of Bali's economy is tourist related.

Like other eclipse watchers headed to the country, *Astronomy* magazine's 2016 eclipse group, organized by TravelQuest International, will headquarter on Bali, flying to and from the viewing site on the days before and after the eclipse.

**The total solar eclipse of March 29, 2006, occurred over much of the Mediterranean region. The photographer caught this complete sequence from a location in Turkey.** JAMIE COOPER

Visitors who join us will encounter Balinese culture in the forms of fine arts (like painting and sculpture) and performing arts, most notably percussion orchestra music and native rituals. Island temples also rank high on the "must-see" list.

Natural sights will include the active volcano Mount Batur and Lake Batur. You'll see both if you ascend (by vehicle) to the rim of the Batur caldera, which lies 5,600 feet (1,700 meters) above sea level.

Last, but not least, you will experience the Balinese New Year celebrations. Locals

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**Michael E. Bakich** is a senior editor of *Astronomy* who will be conducting a huge free public observing event for the August 21, 2017, total solar eclipse in St. Joseph, Missouri.





The path of totality for the March 9, 2016, total solar eclipse carries it across one main landmass — Indonesia. ASTRONOMY: ROEN KELLY

will complete their *ogoh-ogoh*, giant papier-mâché figures of mythological demons. They also will don ceremonial dress and form a procession to the local temple, where they offer gifts to the gods. And finally, as the New Year dawns on the traditional lunar calendar, the *Astronomy* group will find itself in a surprisingly dry but fertile valley on neighboring Sulawesi to watch as the Moon blots out the Sun.

## Eclipse prospects

The narrow path of totality begins at sunrise just south of the equator (at a latitude of  $-2^\circ$ ) in the Indian Ocean some 800 miles (1,300 kilometers) west of Sumatra, which is the first land the Moon's shadow encounters. The path then extends eastward across the southern part of Borneo and through more of Indonesia. After exiting the fourth most populous country on Earth, the Moon's dark inner shadow heads northeast across the North Pacific Ocean, ending at sunset some 1,100 miles (1,800km) northeast of the Hawaiian Islands.

Although the longest duration of totality for this eclipse is 4 minutes and 9 seconds, that span occurs in tropical Pacific waters some 375 miles (600km) southeast



Travelers to Bali may witness the Melasti ceremony of cleansing and purification, as thousands of worshippers in traditional dress form a procession to the Hindu temple. TRAVELQUEST INTERNATIONAL

of Guam. Few, if any, groups or individuals will venture so far afield.

Indeed, most groups with a desire to be on land will view this event within the boundaries of essentially the sole country the total phase of this eclipse touches —

Indonesia. That will be somewhat of a sacrifice because the length of totality even from the easternmost tip of North Maluku Island is 3 minutes and 19 seconds, 50 seconds short of the maximum duration. Unfortunately, weather prospects at that





Bali's central highlands feature the Jatiluwih rice fields, which were named a UNESCO Cultural Landscape in 2012. The terraced paddies cascade down the slopes of Mount Batukaru to the sea. TRAVELQUEST INTERNATIONAL

location are not great, and nearby open land is hard to come by.

*Astronomy* magazine's group will take a more conservative approach. Because Indonesia is a land of tropical humidity,

clouds, and showers, it is a difficult environment in which to view an eclipse. Site selection that takes advantage of normal weather patterns and the ups and downs of the terrain considerably improves the likelihood of seeing the event.

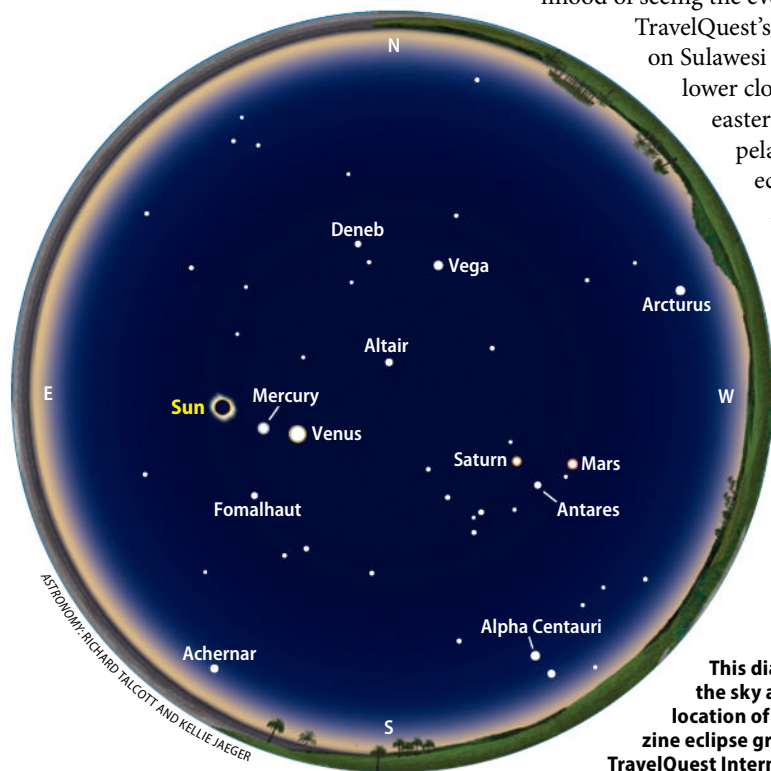
TravelQuest's preferred location on Sulawesi benefits from the lower cloud cover in the eastern part of the archipelago. There, the eclipse track will be moving into a drier and more stable air mass. After studying the topography and all available climatological data and visiting the area, the company's scouting party picked a site where prevailing

air flows will descend from the surrounding mountains, drying the air column and suppressing the formation of clouds.

Most clouds in this part of Indonesia form from the Sun heating the ground during the day. The eclipse at the TravelQuest site begins about 7:30 A.M. local time (time in Central Sulawesi, Indonesia, is eight hours ahead of Greenwich Mean Time, or 13 hours ahead of EST). So, hopefully the cooler morning hours and the brief time between sunrise and totality will keep large-scale clouds from developing.

To a lesser extent, the decline in temperature that comes with the approach of the Moon's shadow will decrease the cloud cover some. Longtime eclipse meteorologist Jay Anderson (who will be on the TravelQuest trip) calculates the potential of cloud cover at the nearby city of Palu at 73 percent.

In addition to the thin zone of totality, a partial solar eclipse will occur over eastern and southeastern Asia, much of Australia, Hawaii, and western Alaska. None of the eclipse is visible from the mainland U.S., South America, Europe, or Africa.



This diagram represents the sky at mid-totality at the location of the *Astronomy* magazine eclipse group, organized by TravelQuest International.

## Eclipse specifics

The day before the eclipse, the *Astronomy* tour group will fly from Bali to Sulawesi, the world's 11th-largest island, and a



location renowned for its spices. At the chosen location, first contact — the moment the Moon's disk takes its first bite out of the Sun — occurs at 7:27 A.M. local time with the Sun 19° above the eastern horizon. Please note that because weather concerns may cause the group to change locations, the times listed are not exact, but they are accurate to within one minute and the altitudes to 1°.

Second contact, or the start of totality, is an hour later, at 8:37 A.M., and third contact — the end of the total phase of the eclipse — occurs a scant 2 minutes and 45 seconds after. Fourth contact, the last visible trace of the Moon's disk against the brilliant solar orb, happens around 10 A.M. local time.

At mid-totality, both Venus and Mercury will be easy to spot. In fact, if the sky is clear between first and second contacts, Venus should appear at least 20 minutes before totality, and Mercury should follow 15 or so minutes later.

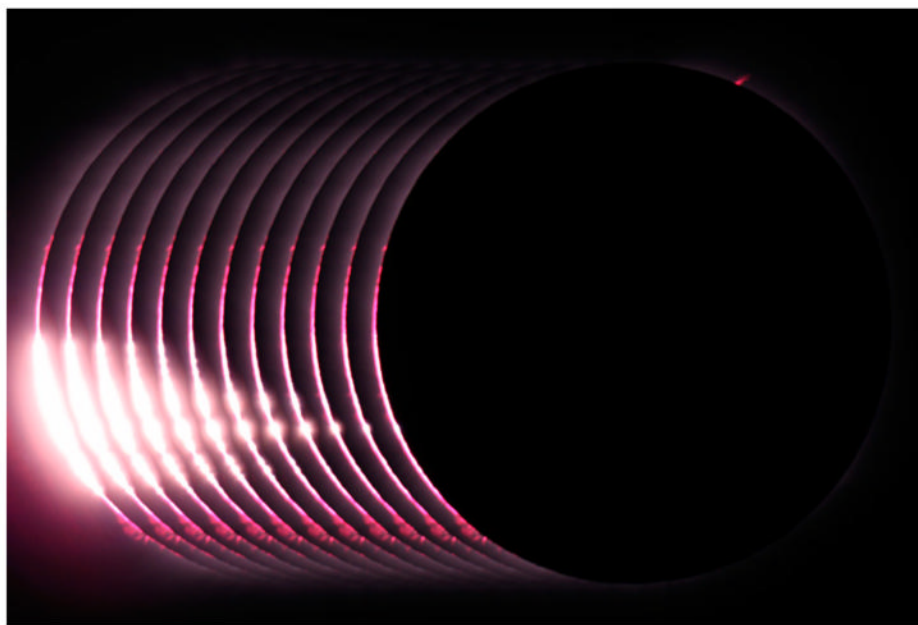
Mercury will be the closer of the two to the Sun. Look 13° west-southwest of our daytime star to find it shining at magnitude -0.6. Before totality, binoculars will help, but if you use them, please take care not to point them at the Sun.

Venus, blazing away at magnitude -3.9, poses no problem at all to spot, especially as the sky begins to darken noticeably. Earth's sister planet will appear 20 times brighter than Mercury.

Because the totally eclipsed Sun stands less than halfway up in the sky, it may be possible to glimpse Mars and Saturn, both much farther away than Venus toward the west-southwest. The Red Planet, shining at magnitude 0.0, lies 108° from the Sun. Saturn, 93° away, is a bit closer but also a bit fainter at magnitude 0.5.

If you plan where to look beforehand (just ask your tour astronomer), start by scanning the area through binoculars, which should reveal both outer worlds. Then you can switch to a naked-eye view to try to see the pair of planets without optical aid. If you choose to attempt this observation, budget only a few seconds for it. After all, the real show lies halfway across the sky where the paths of the Sun and the Moon are intersecting.

Seeing stars during this eclipse will be a bit problematic. You'll spot no really bright star close to the Sun, which lies in the northeastern part of Aquarius the Water-bearer near that constellation's border with



**This series of stacked exposures shows the phenomenon astronomers call Bailey's beads. The bright spots form as the last minuscule fraction of the Sun's disk shines through gaps in lunar valleys or between mountains.** TUNÇ TEZEL



**As the Astronomy group (and many others) drive along Bali's coast, they will encounter the temple of Tanah Lot, which sits offshore on a rocky outcrop sculpted by the tides.** TRAVELQUEST INTERNATIONAL

Pisces the Fish (a notably bright-star-poor region of the sky).

Magnitude 1.2 Fomalhaut (Alpha [ $\alpha$ ] Piscis Austrini) will be the nearest 1st-magnitude star. It stands 26° south of the Sun. With the high humidity of the tropics, your best bet to see it is through binoculars. Magnitude 0.8 Altair (Alpha Aquilae) lies 53° to the eclipse's north-northwest, and magnitude 0.0 Vega (Alpha Lyrae) is 78° to the northwest. Naked-eye sightings of these two luminaries are possible, but again, don't spend more than a few seconds trying to find them. Instead, concentrate on the main event.

## The bigger picture

After all is said and done, the happiest travelers will be the ones who view the eclipse as part of a much larger experience. For them, seeing the Moon's disk blot out the Sun will be a bonus — admittedly a huge one. But their world won't come crashing down around them if eclipse day is cloudy. Adventurers will spend most of the trip exploring the tropical paradise of Bali, and that alone is enough reason to go.

So if you're heading to the tropics next March, we wish you good health, on-time flights, properly functioning cameras, and, above all, clear skies. ☾



# Target asteroids with your binoculars

*Seeing small objects through small optics is easier than you might think.* by Vincent S. Foster

TOMASZ WYSZOLMIRSKI/ISTOCK/THINKSTOCK

**B**elieve it or not, binoculars allow a quick and easy way for you to locate and track bright asteroids as they move across the night sky. Although most asteroids are telescopic objects, some 25 can reach a magnitude brighter than 10.0, which puts them well within range of 10x50 binoculars. By finding and tracking these asteroids, you can greatly enhance your observing skills.

Because asteroids appear as points of light, light pollution does not bother them like it does deep-sky objects. As a result, you can observe them quite successfully from urban and suburban locations.

## Position and movement

Asteroids, also called minor planets, are rocky bodies that orbit the Sun, mostly between Mars and Jupiter. They range in size from several feet to hundreds of miles across. Astronomers think they represent the remnants of the objects that

built the planets during the formation of the solar system approximately 4.5 billion years ago.

Most of the ancient asteroids collided with the major planets. Some of them, however, survived because they lie in areas of the solar system where the gravitational attraction of the planets does not substantially influence them.

Asteroids have orbits that are similar to but generally more eccentric (less circular) than those of the planets. They also have greater inclinations, which means they travel farther above and below the ecliptic (the plane formed by Earth's orbit around the Sun) than most of the planets. The greatest population of

these objects lies in the main asteroid belt located between Mars and Jupiter. This, however, is not the only place where asteroids exist.

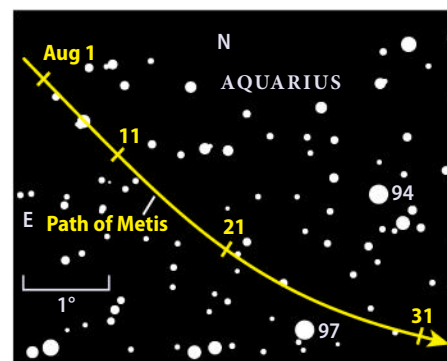
Astronomers have found several populations of minor planets within the orbits of the inner planets, including Earth. This raises the concern of a possible impact that could devastate the fragile atmosphere that sustains

life on our world. The threat is real, but the chance of a major impact occurring during a human lifetime is remote.

## A bit of history

Italian astronomer Guiseppe Piazzi of Palermo, Sicily, discovered the first asteroid January 1, 1801. He named it Ceres, and we now know that it's the largest asteroid in the solar system, with a diameter of 596 miles (960 kilometers). Early asteroid discoveries like this occurred by chance while astronomers were observing or searching for other objects.

Discoveries of two asteroids — Pallas, which measures 354 miles (570km) across, and Vesta, with a diameter of 329 miles (536km) — followed in 1802 and 1807,



The path of 8 Metis during August takes it 0.5° north of the magnitude 5.2 star 97 Aquarii on the 25th.

ASTRONOMY: RICHARD TALCOTT AND RICK JOHNSON

**Vincent S. Foster** has been an amateur astronomer for more than 50 years. He serves as chairman of two of the Astronomical League's observing programs.



respectively. By 1845, astronomers had discovered five such objects, and organized searches began soon after.

The number of new finds increased to five per year by 1865, 15 per year by 1895, and up to about 40 by 1930. Today the number of known asteroids measures in the hundreds of thousands, including some 220 that are larger than 60 miles (100km) across.

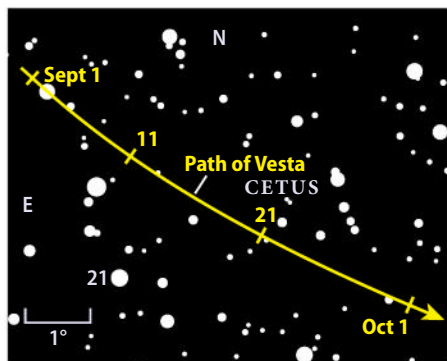
## Types of asteroids

Planetary geologists use asteroids' physical nature to categorize them into three major types based on their color, albedo (reflectivity), and the shape of their spectra. In addition, a significant number of asteroids in the "unknown" category need further study.

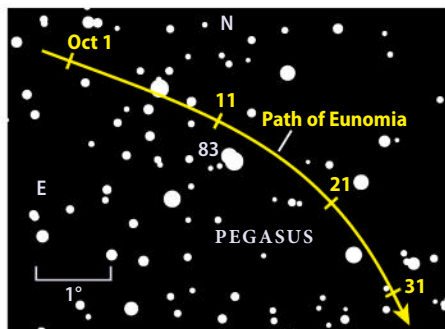
The first broad class, the C-types, for dark carbonaceous objects, represents 75 percent of all known asteroids. C-types are dark in color and typically reflect between 3 and 10 percent of the light that strikes them. Researchers think they are the oldest asteroids, dating back to the formation of the solar system. Objects this old may contain the primordial elements of the original solar nebula and are therefore of great interest to planetary scientists.

S-type asteroids contain silicates and make up about 17 percent of the population. These bodies are not as dark as C-types and reflect between 10 and 22 percent of the sunlight that strikes them. They have a slightly reddish color and contain moderate to high concentrations of iron and magnesium silicates.

X-type asteroids comprise several subgroups. One group's members are even



At around 10 P.M. EDT September 3, 4 Vesta will lie in Cetus within 22" of the magnitude 6.7 star SAO 129056. ASTRONOMY: RICHARD TALCOTT AND RICK JOHNSON



During October, the asteroid 15 Eunomia lies in Pegasus. Keep track of it by centering the magnitude 6.7 star 83 Pegasi. ASTRONOMY: RICHARD TALCOTT AND RICK JOHNSON

more reflective (up to 30 percent) than S-types and may be the core nickel-iron remnants of larger asteroids that broke up due to collisions. They are neutral in color and appear to be composed mainly of metals. Another subgroup contains some of the darkest objects in the solar system. Their reflectivities are all less than 10 percent.

## Designations of asteroids

Astronomers formally refer to an asteroid as a number in parentheses followed by a name, such as (16) Psyche, but most references drop the parentheses. New discoveries receive a provisional designation that includes the year of discovery, two letters, and, if necessary, a subscript.

The first letter designates the half-month of discovery (A through Y, with I unused). The second letter indicates the order of discovery in that half-month (A through Z, with I unused). Astronomers also can add a subscript that shows how many times they've assigned the second set of 25 letters. So, 1953 QT<sub>1</sub> designates the 44th (25 + 19 because of the subscript 1 after the T) asteroid discovered in the second half of August 1953.

## Appearance of asteroids

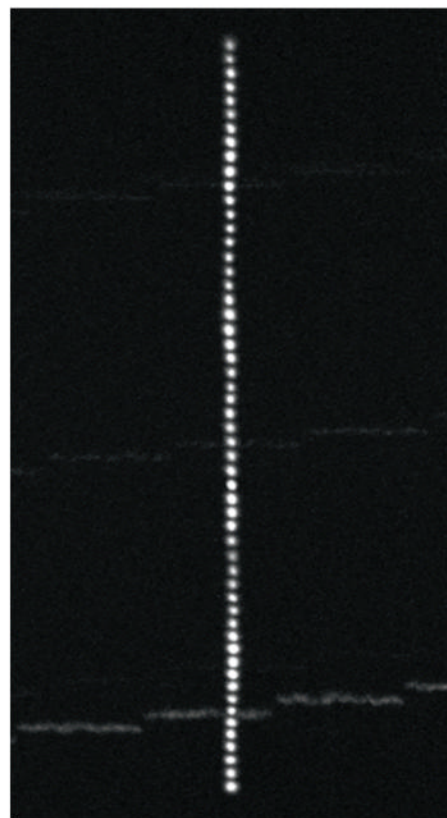
As the name *asteroid* suggests, these objects appear starlike through a telescope. One way to distinguish an asteroid from a star is by its motion, typically 30" per hour relative to the background stars.

Also, unlike most stars, asteroids change in brightness depending on where they lie in their orbits. Asteroids lie much closer to us at opposition than at other times and are therefore brighter and easier to see. Because they lie opposite the Sun from our perspective, they rise at sunset, set at sunrise, and are in the sky all night.

But that's a long-term change. A short-term variance happens because we can detect the irregular shapes and the rough



This stack of eight 2-minute exposures shows asteroid 2005 YU<sub>55</sub> moving through a section of the constellation Pegasus. CHUCK KIMBALL



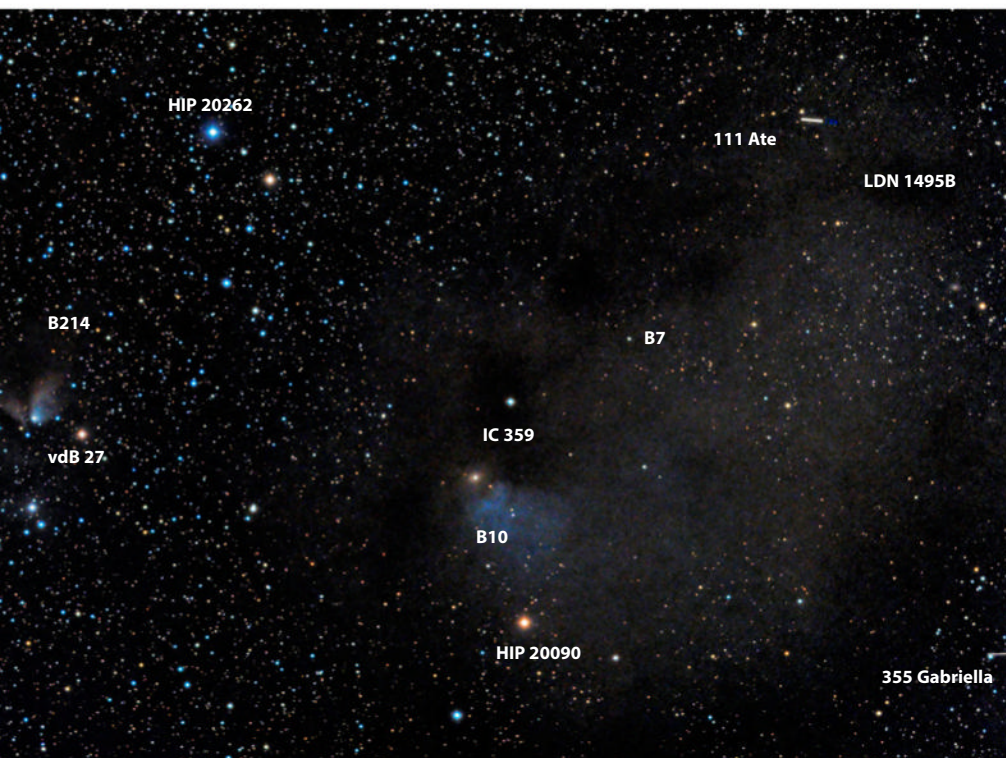
This sequence shows asteroid 2008 TC<sub>3</sub> falling toward Earth. Notice the variation in brightness caused by the asteroid's rotation.

surfaces of asteroids by how much sunlight they reflect. This change, caused mainly by rotation, usually repeats after several hours. Most rotational periods range between five and eight hours, although a few have periods in excess of 24 hours.

## Observing asteroids

As a rule of thumb, use the largest binoculars (those with the biggest front lenses) you can comfortably hold while targeting an asteroid. For most people, this will mean 7x50s. A few beefier souls will be able to manage 11x70 binoculars or perhaps even larger.

The way to circumvent this limit is to mount your larger (or heavier) binoculars



This image shows reflection nebula IC 359 and three dark nebulae: Barnard 7, B10, and B214. During the 5 hours and 50 minutes of exposures, however, asteroid 111 Ate (upper right) and asteroid 355 Gabriella (lower right) made streaks. DAN CROWSON

on a tripod. Then you can take all the time you need to identify your target.

To find an asteroid in the night sky, you will need a high-quality star map so you can plot the object's right ascension and declination. Make sure the information is accurate for the date that you will be observing. Remember, as they orbit the Sun, asteroids change their positions against the background stars. At certain points in their orbits, they even may change position over a period of just a few hours.

You'll find locations of currently bright asteroids in "The Sky this Month" section of *Astronomy*. For example, this issue plots the path of Ceres for the whole month.

Because asteroids look like stars, you will need to have a way of determining which point is actually the asteroid. Usually a good finder chart will be enough to accurately identify the asteroid, especially if you know its approximate position and magnitude. If you're using a chart that doesn't show enough stars, then you will need to use another method to determine which object is the asteroid.

The simplest way of doing this is to sketch the star field, return to the same field an hour or so later, and check to see if any objects on your drawing have changed



This stack of three 2-minute images shows asteroid 1998 QE<sub>2</sub> when it was 3.6 million miles (5.8 million kilometers) from Earth, moving at approximately 21' per hour and glowing at 11th magnitude. DAMIAN PEACH

position. If one has moved, it likely will be the asteroid. The length of time needed for you to detect motion will vary, so you may have to check back a few times — or even on the following night — before you see it.

The International Astronomical Union's Minor Planet Center (MPC) maintains a website that contains resources to assist you in finding asteroids and helping you develop a list of targets to observe. You can even visit the MPC's Minor Planet Ephemeris Service and download a file for any asteroid that lets you track it in real time and print your own finder charts.

## A LIST OF BRIGHT ASTEROIDS FOR BINOCULARS

Asteroid	Brightness range (at opposition)	Average brightness (at opposition)
4 Vesta	5.3 to 6.5	6.0
1 Ceres	6.7 to 7.7	7.2
7 Iris	6.7 to 9.5	8.5
2 Pallas	6.7 to 9.7	8.6
3 Juno	7.5 to 10.2	9.1
6 Hebe	7.7 to 10.0	9.1
18 Melpomene	7.7 to 10.4	9.4
15 Eunomia	7.9 to 9.9	8.9
8 Flora	8.0 to 9.8	9.0
324 Bamberga	8.1 to 12.1	10.9
9 Metis	8.2 to 9.7	9.2
192 Nausikaa	8.2 to 11.3	10.3
20 Massalia	8.4 to 10.1	9.4
27 Euterpe	8.4 to 10.6	9.7
12 Victoria	8.6 to 11.2	10.2
29 Amphitrite	8.7 to 9.6	9.2
11 Parthenope	8.8 to 10.1	9.6
5 Astraea	8.8 to 11.1	10.3
43 Ariadne	8.8 to 11.1	10.3
89 Julia	8.8 to 11.2	10.3
39 Laetitia	8.9 to 10.4	9.8
44 Nysa	8.9 to 10.7	10.0
19 Fortuna	8.9 to 10.9	10.2
10 Hygiea	9.0 to 10.3	9.8
14 Irene	9.0 to 10.7	9.9

Or try CalSky.com. This handy website calculates asteroids by magnitude that are visible from your location. Visit [www.calsky.com](http://www.calsky.com), select "Asteroids" from the main page, and choose "Nighttime Asteroids" on the following page.

Enter the start date, duration, and magnitude you wish to search. This will generate a list of asteroids along with their magnitudes, locations, background star charts, and other data. Because you're using binoculars, keep the magnitude criterion at 10 or brighter.

## Scan for small bodies

The magnitude limit you can achieve on any given night doesn't depend just on the size of your binoculars. Other things like sky conditions, how much light pollution or moonlight there is, the quality of your equipment, and your observing experience factor in as well. As you scan the heavens for asteroids, remember the old adage: The sky rewards patient observers. ☿



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Rebate \$ 200  
Now \$ 899



N A140SS Reg \$1999  
Rebate \$ 400  
Now \$1599



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P24157

William Cho (landscape); Mike Reynolds (eclipse)



# Tour 10 fall binocular treats

*Take your binoculars to a dark site this season, and you'll enjoy a night of easy observing.* **by Phil Harrington**

**A**utumn is a season of transition, both here on Earth as well as in the sky. Summer's brilliant Milky Way paves the western sky while the first hint of winter's jewels peek above the eastern horizon. In between, we can choose from a multitude of binocular targets both near and far.

The queen of autumn, Cassiopeia, is chock-full of open star clusters visible through binoculars. Sit back in a reclining chair, and scan the familiar W pattern. You'll pass many little clumps of stardust.

One that you'll see is **NGC 225**, also known as the Sailboat Cluster, dwelling about halfway between Gamma ( $\gamma$ ) and Kappa ( $\kappa$ ) Cassiopeiae. While it may not be the brightest cluster within the constellation, it was apparent through my 10x50 binoculars under a dark sky last year. Switching to my 16x70s, NGC 225 evolved into a small semicircle of 10 faint points engulfed in a field of myriad other stars.

**NGC 559** is another of the Queen's clusters worthy of your attention. You'll find it roughly halfway between Gamma and Epsilon ( $\epsilon$ ) Cassiopeiae. Although it

shines at only magnitude 9.5, NGC 559 is still easily visible through 7x35 binoculars from rural skies.

Some 120 stars populate this densely packed group, but only a third are 11th magnitude or brighter. So, while we may not be able to see many individual stars, together they create a 7'-wide mist of stardust just west of a compact trapezoid of 7th-magnitude stars.

Although he doesn't command the attention of the Queen, the constellation Cepheus the King nonetheless holds several worthy binocular targets. One that few observers notice is the quadruple star **15 Cephei**. The famous Ukrainian-American binary star observer Otto Struve included this wonderful group in his double star catalog as number 461.

Here, binoculars show a pretty string of three white stars — all exactly alike — in a straight line with a fainter star off to the southeast. It reminds me of a miniature version of summer's Coathanger asterism (Collinder 399), sans hook.

Toward the east-southeast lies one of autumn's showpieces: the Double Cluster

in Perseus (NGC 869 and NGC 884). It's worth revisiting every time you head out this time of year. But next time, rather than just glance-and-go, pause and take in its surroundings. You'll find hidden treasure here. Look carefully through your binoculars about 1.5° east-northeast of NGC 884, the eastern member of the Double Cluster.

Can you see open cluster **NGC 957**? While it can't compete with its neighbors, it's still a fun catch. Look for an arc of three faint stars curving away from the group's misty center. The cluster glows at 8th magnitude, so wait until it is high in the sky for the best view.

Did you know that there is another "double cluster" in Perseus? The pair lies near a double triangle formed by Lambda ( $\lambda$ ), Mu ( $\mu$ ), 48, and 53 Persei. The easier of the pair to spot is **NGC 1528**. Under dark skies, my 10x50 binoculars show a perfectly round smudge of distant starlight just beyond a tiny Y-shaped pattern of stars.

Its companion, **NGC 1545**, is tough to spot even through large binoculars. All I make out is a subtle hint of its existence around the faint stars SAO 24556 and SAO



Magnitude 6.4 NGC 1528 is at the limit of naked-eye visibility. Binoculars reveal it easily, however, from a dark site. ANTHONY AYIOMAMITIS



The constellation Aquarius the Water-bearer features the asterism of the Water Jar. In this image, the four bluish stars that form a Y shape near the top mark this celestial pattern. BILL AND SALLY FLETCHER





Open cluster NGC 957 in Perseus glows at magnitude 7.6. The bright star below the center of the cluster is magnitude 8.0 HIP 11898. ANTHONY AVIOMAMITIS

24554. Even my 25x100 giant binos add only a few dim points within.

Southward now, we head toward Aquarius. While the Water-bearer contains no bright stars, it is home to a Y-shaped asterism of 4th-magnitude stars that fits nicely into most binocular fields of view. Known as the **Water Jar**, Gamma Aquarii is at the center, while Pi ( $\pi$ ), Eta ( $\eta$ ), and Zeta ( $\zeta$ ) Aquarii mark the bottom of the Y and its two branches.

In drawings of the constellation, seven streams of faint stars flowing southward from the Water Jar represent water pouring toward the bright star Fomalhaut (Alpha [ $\alpha$ ] Piscis Austrini) and into the mouth of the constellation of the Southern Fish.

The three most obvious streams include 88, 89, and 86 Aquarii; 98, 99, and 101 Aquarii; and 103 through 108 Aquarii. How many others can you trace through your binoculars?

In his privately published book *Asterisms for Small Telescopes and Binoculars* (Brunswick Publishing, 2005), author John Raymond noted that there is another water jar in nearby Pisces. Dubbed the **Little**

**Water Jar**, it includes 8th-magnitude SAO 146605 as the center, with SAO 146600, SAO 146609, and SAO 146617 as the three branches. Three other stars to the southeast — SAO 146627, SAO 146631, and SAO 146632 — create a trickle of water.

Let's stay within Pisces and hunt down some truly big game. Big game in this case also will require big binoculars because we are looking for spiral galaxy **M74**. To find it, first locate 4th-magnitude Eta Piscium. Eta and two fainter stars create a small triangle that points toward Aries. M74 lies almost centered inside this triangle.

Photographs reveal M74 as a lovely face-on spiral with thin curved arms. All we can hope to see through binoculars, however, is a dim glow only slightly brighter than the surrounding sky. Mounting your binoculars on a tripod or other support is mandatory here, as is using averted vision.

Also, once you think you have the galaxy in the field of view, try lightly tapping the side of your mounted binoculars. Our eyes detect low-surface-brightness objects more readily if they are shifting back and forth slightly instead of just sitting motionless. I've used this technique successfully to observe M74 through my 16x70 binoculars.

Our next target takes us outside the realm of recognized objects. Before 1928,

when the International Astronomical Union codified the 88 constellations we know today, many astronomers and map-makers created and named their own patterns that have since been abandoned. One such example is **Musca Borealis**, the Northern Fly, which occupied a position in the current constellation Aries the Ram.

The Northern Fly used to be the stars we know today as 33, 35, 39, and 41 Arietis. Actually, the pattern began as Apes the Bee in 1612. It later evolved into a wasp before becoming a fly on Johannes Hevelius' atlas, *Firmamentum Sobiescianum*, which appeared in 1690.

It was finally named Musca Borealis on Alexander Jamieson's *Celestial Atlas* of 1822 to distinguish it from the Southern Hemisphere's fly constellation, Musca, which remains today. Can you spot Jamieson's Northern Fly through your binoculars? Look 13° west of the Pleiades. Although none of the stars shines brighter than 4th magnitude, they still create a little triangular asterism that's easy to swat ... I mean, spot.

Do you have some favorite binocular targets I haven't written about? I'd like to hear about them. Contact me by visiting <http://philharrington.net>. And remember, two eyes are better than one. ☿

**Phil Harrington** is an Astronomy contributing editor and author of *Cosmic Challenge* (Cambridge University Press, 2010).



# Astronomy tests Daystar's Quark

*Ease of use, extreme portability, and a great price make this Hydrogen-alpha solar filter one to consider.* **by Michael E. Bakich**

**H**ere's a prediction that I know will come true: In the next two years, interest in solar observing will rise dramatically. You probably can guess why. With the great solar eclipse of August 21, 2017, in our future, lots of people will want to prepare by purchasing a filter to view the Sun through.

Most will buy visual solar filters, also known as "white-light" filters. Such an accessory blocks harmful infrared and ultraviolet radiation and reduces the Sun's visible light to a comfortable level. Such filters let you see sunspots.

But if you want to see more than just sunspots, you'll need to move into the realm of Hydrogen-alpha (H $\alpha$ ) observing. Daystar Filters, a company that has been making such products for decades, has introduced a new player — the Quark — into that arena. It combines an all-in-one unit and the ultimate in portability with a price point below all but the smallest H $\alpha$  filters.

## Is that an eyepiece?

At first glance, you might mistake the Quark for a sleek 2" eyepiece. Daystar gave



**Daystar's Quark is a Hydrogen-alpha filter that fits into your telescope's focuser. The unit weighs only 13.9 ounces (394 grams).**

ALL PRODUCT IMAGES: ASTRONOMY: JAMES FORBES

this product a cool look by anodizing the aluminum body black and red. The company also maximized its use (and sales) by making it fit both 2" and 1 1/4" focusers. The filter outputs to a 1 1/4" eyepiece (or camera adapter) using a brass compression ring to avoid marring the barrel, and the company does sell a 2" eyepiece holder for \$45. To use it, you just unscrew the 1 1/4" one and screw in the larger piece.

Daystar designed the Quark to work on refractors with focal ratios from f/4 to f/8, which immediately puts it in play with "grab-and-go" scopes. The filter has an internal heater that requires power to operate, and you can get that power in two ways: either from a USB 3.0 port (5 volts, 1.5 amps) or via the 90–240VAC wall adapter (that even comes with international plug adapters).

If you plan to do a lot of observing away from home, I suggest you also purchase the 30-amp battery pack (QBP30) that Daystar offers for \$89. This unit has both 2-amp and 1-amp USB outputs (the Quark filter uses the 2-amp one) and a solar panel that recharges it on site. Because the Quark requires 1.5 amps, a fully charged battery

pack will run it all day, even without the solar-panel recharging.

## The big choice

Because no single filter is perfect for all applications, Daystar produces two versions of the Quark: Chromosphere and Prominence. As the names indicate, each has its specialty, although there's enough overlap that you will see prominences through the Chromosphere filter and surface details through the Prominence unit.

Technically, Daystar separates the two varieties by stating that the bandpass of the Prominence filter is from 0.8 to 0.6 angstroms while the Chromosphere filter is from 0.5 to 0.3 Å. "Bandpass" is the range of wavelengths the filter lets through. Each filter centers on the wavelength of the H $\alpha$  line, 656.28 nanometers (or 6562.8 Å, which conforms to the units the company gives the bandpass in).

## A bit of tech

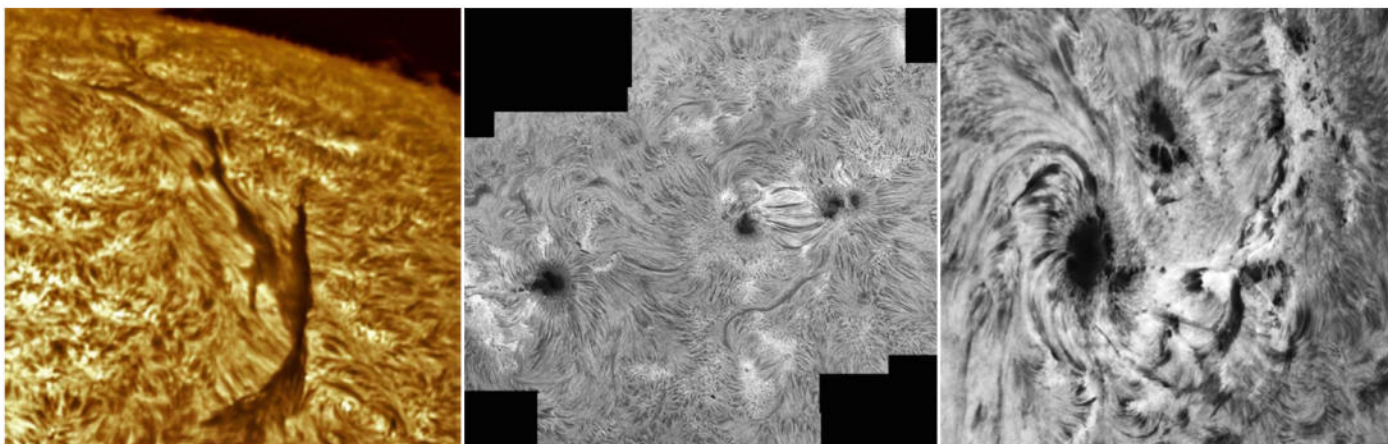
The Quark is a 4.2x telecentric Barlow lens that incorporates a 21-millimeter H $\alpha$  filter and a 12mm blocking filter. All optical elements receive anti-reflective coatings at the factory. To further reduce scattered light (which decreases image contrast), the company has built the unit with a series of internal baffles.

H $\alpha$  filters that attach to the eyepiece end of a refractor often require an extra energy-rejection (ER) filter in front of the objective lens (that is, between it and the Sun). That pre-filter gets rid of much of the harmful radiation before it enters the main filter. If you mount the Quark on a 6-inch (150mm) or larger scope, use an ER filter at the front of the telescope.

The other time you'll need to use an ER filter is if your telescope has optics at other

**Michael E. Bakich** is a senior editor of *Astronomy*. He will be hosting a free public-viewing event at Rosecrans Memorial Airport in St. Joseph, Missouri, during the total solar eclipse August 21, 2017. See [www.fpsci.com](http://www.fpsci.com).





In addition to using the Quark to observe visually, purchasers of the unit also are imaging the Sun through it. These three examples show some of what's possible. (The photographer gave the leftmost image a yellow tint during processing.) LEFT TO RIGHT: GARY PALMER; JOE SULLIVAN; RANDY SHIVAK

points within the tube. One example of this is the Petzval design. Without an ER filter, the two lens elements inside the tube would become too hot.

If your objective is less than 6 inches in diameter, you can use an optional UV/IR blocking filter Daystar sells (DSIUV2, \$120). Just screw the filter onto the front of your star diagonal, and drop the Quark into the other end.

Daystar states that you can use the Quark without any ER filter for occasional views of the Sun on telescopes with apertures less than 3.15 inches (80mm) and non-tracking mounts. In both cases, excessive heat wouldn't build up within the scope. And, indeed, I had no problems viewing through my 3-inch alt-azimuth-mounted refractor without a filter off and on for several hours.

The only knob on the Quark controls the heater, which really determines what the central wavelength is. Each detent on the knob shifts it by 0.1 Å, and the filter allows a 0.5-Å adjustment either way. This puts different details — as well as some that are rotating toward or away from you — “on band.” Just be sure to give the filter

a few minutes to attain the new temperature once you rotate the knob. One nice feature the company included is an LED that changes from yellow to green when the filter is on band.

Daystar claims that from a cold start the Quark takes approximately 15 minutes to reach operating temperature (the LED turns green). I can confirm that length of time as an average, although on one sunny 20° F (–7° C) day in Wisconsin when I used the optional power supply, the heating element required an additional five minutes to warm up (and I never did get warm).

And here's a tip I thought of only after my first two observing sessions with the Quark: Plug the filter into the power supply first, even before you set up your telescope. You can even do this on the way to your observing site. Then, once you've set up your scope, carefully attach the Quark without unplugging the power cord from the battery pack. It will be at temperature and ready to rock.

## The views

The Quark helped me remember why I love observing the Sun. Once the LED turned green, I saw prominences, faculae, flares, and, yes, even sunspots. I didn't concentrate on the spots themselves because there was such a vast amount of detail near them.

One of the cool things about solar viewing is that some of the Sun's features, mainly prominences and flares, show noticeable changes in real time — in just minutes. I saw tree-shaped prominences reform into arcs and then to spouts within 15 minutes. And in twice that time, I observed flares, which appear as bright (even overexposed) regions, sending out tendrils from which new flares formed.

I did some experimenting with the Quark's heater knob, although I really didn't need to. The on-band views never disappointed me. After trying numerous settings (and waiting for the green “Go” LED), I found only twice when the view of part of the solar scene (once a set of prominences and the other time a sunspot group) improved. Still, the  $\pm 0.5\text{-}\text{\AA}$  control is a nice option to have.

## The verdict

For me, three things made the Quark great fun to use. First, it's not a complicated setup: plug in power; insert into focuser; and observe. Second, the device is ultra-portable. It and its power supply (bubble wrapped) fit into my fabric telescope case. And third, when coupled with my 3-inch refractor, views through the Quark surpassed my expectations.

I love observing the Sun and turning people on to how utterly cool it is. Daystar has given me something new to suggest to them that won't break the bank. ☼



Two optional accessories you'll want to consider are the UV/IR blocking filter (above) and the 2" eyepiece holder.



## PRODUCT INFORMATION

### Daystar Quark Hydrogen-alpha filter

**Optical design:** 4.2x Telecentric  
Barlow lens

**Models:** Chromosphere and Prominence

**Power requirement:** USB 5 volts, 1.5 amp

**Weight:** 13.9 ounces (394 grams)

**Price:** \$995

**Contact:** Daystar Filters

149 Northwest OO Highway  
Warrensburg, MO 64093

[t] 866.680.6563

[w] [www.daystarfilters.com](http://www.daystarfilters.com)



# Field of view indicators

Field of view (FoV) indicators are fundamental tools for imagers. They can show you whether an object will fit in the FoV created by the combination of the optical system and the sensor size.

If an object does not fit, you can use FoV indicators to construct a mosaic of fields to shoot. Finally, if you're using an autoguider, FoV indicators also can determine if guide stars are available. In this article, I describe how to use the *Aladin Sky Atlas* (imagers usually just call it *Aladin*) to make your own FoV indicators.

Normally, you would construct FoV indicators using commercially available planetary programs. As part of my job at the Mount Lemmon SkyCenter, I make telescopes available for remote observing (see <http://skycenter.arizona.edu>). So, I face the problem of communicating what the FoV is for a given telescope without requiring users to own software. *Aladin* is a great solution because it is free and displays this information and more.

Visit <http://aladin.u-strasbg.fr> to download the program.

When you run *Aladin*, it presents you with a screen that looks like Image #1. By default, the program uses the color images of the Digitized Sky Survey (DSS), although you can select other all-sky surveys. Simply type an object name or a coordinate in the "Location" field, and press "Enter." You will see the DSS image of that region of sky. Using the controls to the right of the sky image, make adjustments by panning and zooming.

Look in the "File" menu and select "Load Instrument FoV" to see a list of presets astronomers often use (Image #2). I highlighted the entry for the 32-inch Schulman Telescope at the SkyCenter (you are supposed to be impressed). After pressing the "Submit" button, the DSS image will have an overlay with your chosen FoV. *Aladin* treats overlays just like a layer in Photoshop. You can modify their attributes in the "Stack" controls section (Image #3). Zoom out enough to see

## FROM OUR INBOX

### Political potshots

I am disappointed once again by *Astronomy* taking political potshots: "Senator Ted Cruz, a climate change denier who pushed to cut NASA funds in 2013, now chairs the committee that oversees NASA and science. The fox guards the hen house" (Cosmic World, May 2015). This isn't the first time this has happened. For some reason, the editors at *Astronomy* must think that all professional and amateur astronomers, especially its subscribers, are left-wing atheists. I am neither left wing nor atheist. What I am is a person who likes to read and learn about astronomy from multiple sources. If I want political commentary, I'll watch the talking heads on TV, not see what *Astronomy* has to say on the subject. If I want to listen to someone disparage my faith — and I cannot ever think I'll want that — I doubt that I'll be attentive to Bob Berman. Stick to what you used to do well and leave the potshots for someone else.

— Tom Zerfas, Hays, Kansas

the entire FoV, or it will look like it just colors the screen.

So now you can plan your imaging sessions for the Schulman Telescope at your leisure! However, you may want to do this for your own system, so in the FoV section, find a button called "Create your Own." In the video associated with this article (see [www.Astronomy.com/Block](http://www.Astronomy.com/Block)), I show you how to calculate the FoV for your telescope and camera, create rectangles and circles with the correct dimensions, and then save the result. You will have created a file with a VOT extension that you can load any time you need to.

Separate autoguider chips require a little more effort

because they are offset from the center of the FoV. You will need to determine offsets for internal guiders by looking up the published separation of the chips for your system in millimeters and converting to arcseconds. For an off-axis guider, you can determine the separation of the chips on the sky by centering a star on each chip and recording how far the telescope moved in arcseconds.

Not only is *Aladin* fun to use, but its FoV indicators should be one of the essential tools you have in your astrophotography toolbox. In my next column, I will discuss dark frames and the use of master darks that persist for extended periods of time. ☿



Image #1. Here is the initial screen for the *Aladin Sky Atlas*. Type an object's name or designation in the "Location" field highlighted in yellow near the top, and a Digitized Sky Survey image will load in the square viewer window. ALL IMAGES: ADAM BLOCK

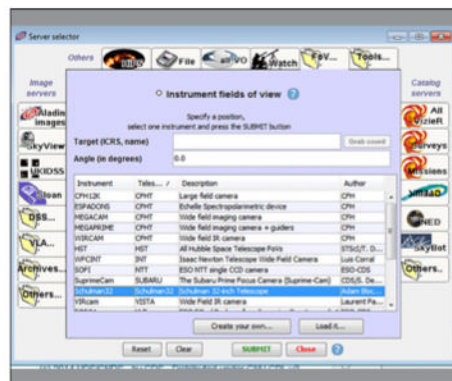


Image #2. Load the "Instrument FoV" under the "File" menu to enter this screen. Create a FoV (once) and then load it each time you use *Aladin*. Press the "Submit" button to overlay the FoV, then look back at the main screen. See the author's video at [www.Astronomy.com/Block](http://www.Astronomy.com/Block).

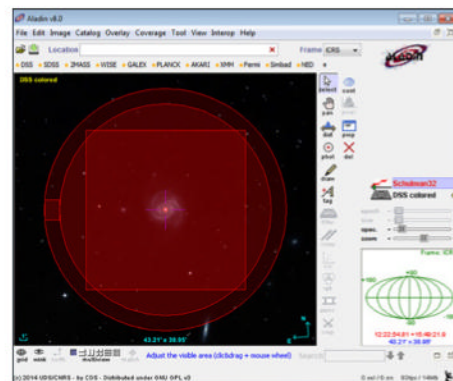


Image #3. A FoV indicator is now an overlay. Controls are to the right. Right click on the FoV layer to adjust its properties. The FoV shown here is for a dual-chip camera with an internal autoguider represented by the small rectangle. Stars between the outer rings are potential guide stars.



# NEW PRODUCTS

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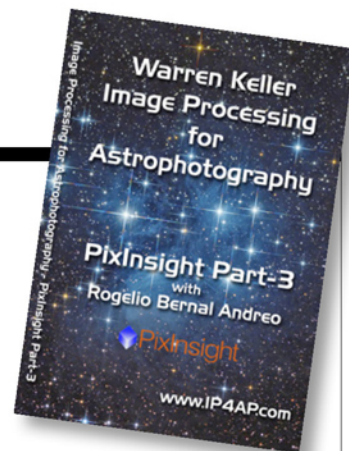


## Solar glasses

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Reseda, California  
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## Refractor

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## The Real Reality Show



### It's time to turn on your mind

With the incredible availability of all kinds of mindless entertainment today, many people are losing large chunks of their time to things that have nothing to do with reality. Some are ignorant to the countless true wonders of the universe, and the often sensationalist 24-hour news media make the situation worse.

With these concerns in mind, Editor David J. Eicher brings you *The Real Reality Show*, a Web series dedicated to sharing what's *really* going on in the cosmos. In just a few entertaining minutes every other week, Eicher cuts to the chase with popular topics in both science and sci-fi, tackling everything from UFOs and interstellar travel to the Big Bang and black holes. Each episode provides a fun way to share astronomy with those friends who are too absorbed in the countless "reality" shows out there to unplug their TVs and plug into the amazing things we're learning about our universe. Start spreading the word by visiting [www.Astronomy.com/realreality](http://www.Astronomy.com/realreality).



### OBSERVING TOOLS

#### "How to Observe Meteor Showers"

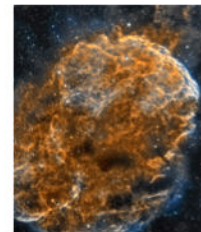
Meteor showers are one of the most popular celestial events because they don't require any observing experience — only comfort and patience. And August brings the biggest shower of 2015, as the Perseids peak under Moon-free conditions. To prepare for these "shooting stars," check out Senior Editor Michael E. Bakich's video "How to Observe Meteor Showers." In it, he explains the basics of what causes these events, where and when to watch, what to bring, what to take note of, and much more. Let Bakich help you get ready for August's Perseids at [www.Astronomy.com/intro](http://www.Astronomy.com/intro).



### COMMUNITY

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Browse thousands of images like this one of the Jellyfish Nebula by Juan Ignacio Jimenez. Submit your own at [www.Astronomy.com/readergallery](http://www.Astronomy.com/readergallery).



#### Year of Pluto blog

Follow along with *Astronomy* magazine as the New Horizons mission reveals Pluto's long-held secrets and relive the history that led us to this solar system frontier at [www.Astronomy.com/year-of-pluto](http://www.Astronomy.com/year-of-pluto).



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1

## 1. SPECTACULAR SATELLITE

The Small Magellanic Cloud orbits our Milky Way and contains lots of deep-sky objects. The two bright blue patches to the left are NGC 371 (left-most) and NGC 346, open clusters surrounded by nebulae containing lots of oxygen, which gives them their color. Open cluster NGC 330 lies to the right of NGC 346. (4-inch Takahashi FSQ-106 refractor, SBIG STL-11000M CCD camera, LRGB image with exposures of 450, 140, 160, and 290 minutes, respectively) • *Ron Brecher and Brett Soames*

## 2. GEOMAGNETIC STORM

This contributor wanted to show the precise geometry of star trails and the rapidly moving northern lights. Several frames also capture a car passing by at lower right. (Canon 6D DSLR, 24mm lens set at f/4.5, ISO 2000, two hundred and sixty-five 15-second exposures, stacked, taken March 17, 2015, from Big Bay, Ontario, Canada) • *Steve Irvine*



2





### 3. LIGHT IN THE DARKNESS

Lynds Dark Nebula 988 is the large dark patch at center, and within it lies a blue reflection nebula. Sharpless 2–120 lies to the upper left of LDN 988, and Sh 2–121 lies farther in the same direction. (8-inch Officina Stellare Riccardi-Honders RH 200, SBIG ST-8300M CCD camera, LRGB image with exposures of 140, 80, 60, and 80 minutes, respectively) • **Harel Boren**



### 4. OUTER SPACE MASH-UP

Sharpless 2–216 (center) is one of the closest planetary nebulae to Earth. To its right is the supernova remnant Sh 2–221. The small bright object to the lower right is emission nebula Sh 2–219. (Canon 450D DSLR, Canon EF200 f/2.8L II USM lens set at f/3.5, seventeen 10-minute exposures at ISO 200, eighty-five 10-minute exposures at ISO 1600 through an H $\alpha$  filter, and fifty-two 10-minute exposures through an OIII filter) • **Scott Rosen**

### 5. MOON DANCE

This sequence shows two of Jupiter's satellites. From top to bottom, Io (the smaller body) emerges from Jupiter's shadow and then Ganymede occults it. (17.5-inch Dobsonian-mounted Newtonian reflector, ASI 174MM CCD camera, taken April 21, 2015, from St. Albans, England) • **Martin Lewis**



### 6. GREAT NEIGHBORHOOD

Ignore the bright stars, and look for the tight group near the center. That's the magnitude 10.9 open cluster NGC 2192 in Auriga. (3.6-inch Astro-Tech AT90DT refractor at f/6.7, SBIG ST-8300M CCD camera, LRGB image with exposures of 60, 40, 40, and 40 minutes, respectively) • **Dan Crowson**

### 7. SAGITTARIUS MOSAIC

This image covers an area of sky 7.1° by 4.1°. The Eagle Nebula (M16) lies at upper right, the Omega Nebula (M17) is the bright region above center, and open cluster M25 lies at upper left. (7.2-inch Takahashi E-180 F2.8 Astrograph, QHYCCD QHY11 CCD camera, four-panel mosaic, each of which is an H $\alpha$ LRGB image with exposures of 72, 12, 12, 12, and 12 minutes, respectively) • **Terry Hancock**



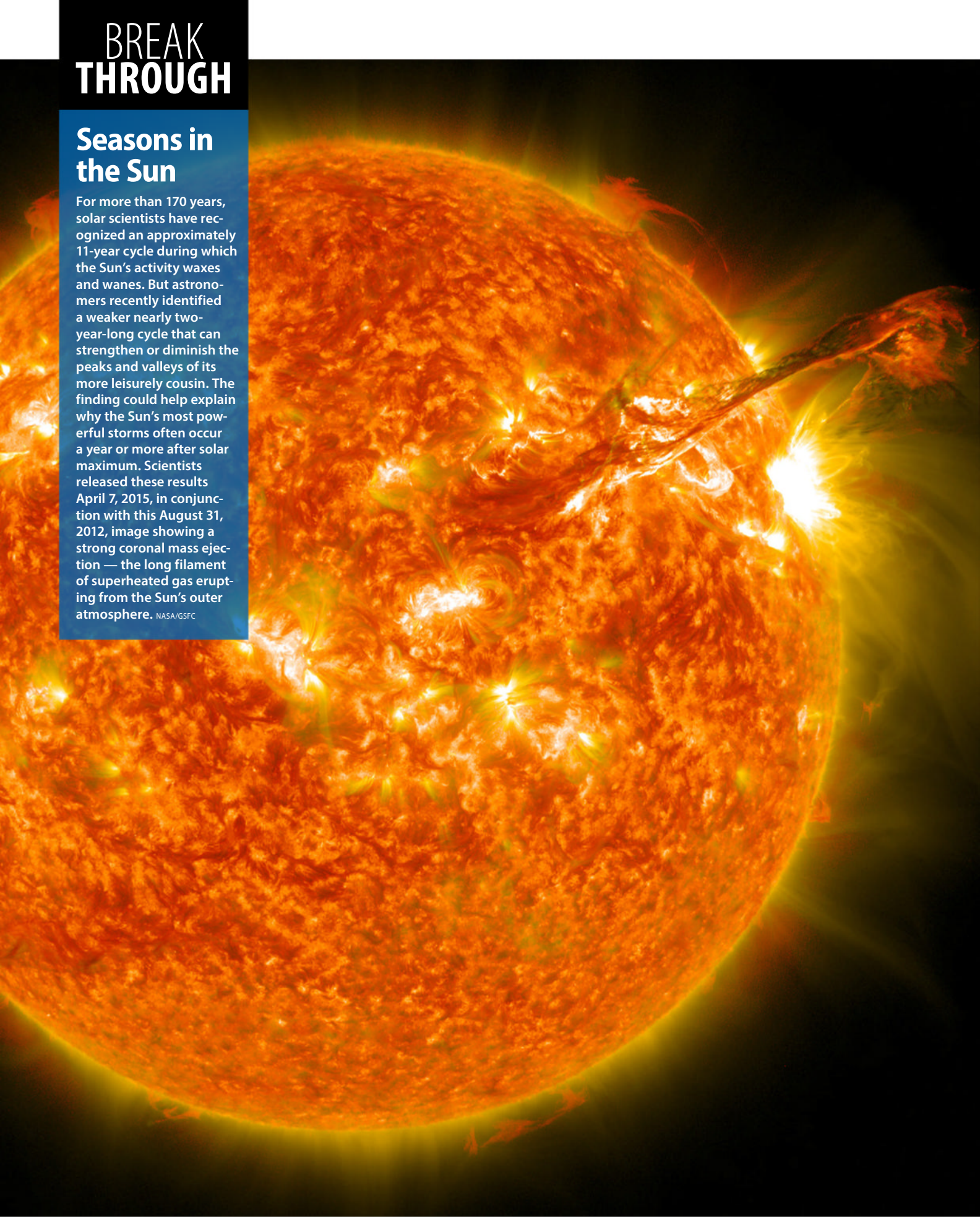
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## Seasons in the Sun

For more than 170 years, solar scientists have recognized an approximately 11-year cycle during which the Sun's activity waxes and wanes. But astronomers recently identified a weaker nearly two-year-long cycle that can strengthen or diminish the peaks and valleys of its more leisurely cousin. The finding could help explain why the Sun's most powerful storms often occur a year or more after solar maximum. Scientists released these results April 7, 2015, in conjunction with this August 31, 2012, image showing a strong coronal mass ejection — the long filament of superheated gas erupting from the Sun's outer atmosphere. NASA/GSFC





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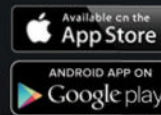


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# October 2015: Morning planets galore

The night sky offers a glowing reminder that spring has arrived. Each evening, the familiar form of Scorpius the Scorpion dives toward the western horizon. This year, however, a bright planet adds to the scene. **Saturn** sits near the border between Libra and Scorpius all month, officially crossing into the Scorpion in mid-October. On the 24th, the magnitude 0.5 world passes 0.7° due north of 2nd-magnitude Beta (β) Scorpii.

Saturn inches closer to the western horizon each evening, a sure sign that its days as a telescopic wonder are numbered. It stands some 30° high at the end of twilight October 1 but just 5° high on the 31st. Take some time in early October to enjoy the planet's ring system, which spans 36" and tilts 25° to our line of sight.

While Saturn is the lone naked-eye evening planet, the early morning sky provides a feast. In early October, brilliant **Venus** rises first. It pokes above the eastern horizon in the company of the background stars of Leo the Lion some two hours before the Sun. On the 9th, the planet passes 3° south of that constellation's luminary, Regulus. At magnitude -4.7, Venus shines nearly 300 times brighter than the star.

The planet reaches greatest elongation from the Sun on October 26, when it stands 46° west of our star. This timing means the entire month is great for viewing Venus through a telescope. On October 1, it appears 33" across and one-third lit; by the 31st, its disk

spans 23" and the Sun illuminates just over half of it.

On the same day that Venus achieves greatest elongation, it passes 1.1° due south (upper right) of **Jupiter**. Although Jupiter pales in comparison to its neighbor — at magnitude -1.8 it is less than 10 percent as bright — it still outshines every star in the night sky.

As Jupiter gains altitude in the predawn sky, it becomes a tempting target for those with telescopes. The giant planet's four moons show up easily as they dance to the tune of orbital dynamics. During moments of steady seeing, when turbulence in Earth's atmosphere quiets down and instruments deliver crisp views, you'll also see detail in Jupiter's cloud tops. On the 31st, the world's disk spans 33" across its equator.

Seeing Venus and Jupiter close to each other always provides a thrill, and people invariably call my planetarium to ask what those two bright points of light are. But the solar system outdoes itself this time by adding a third planet to the vista. **Mars** passes 0.4° north of Jupiter on October 17. The Red Planet then shines at magnitude 1.7 and forms a pretty pair with the giant world some 7° to Venus' lower right. For the rest of October, the three planets all show up in a single field of view through typical 10x50 binoculars. Unfortunately, a telescope doesn't measurably improve the appearance of Mars, which shows a featureless disk merely 4" across.

Be sure to catch the Moon's passage through this part of the

sky October 9 and 10. The highlight comes before dawn on the 9th, when the waning crescent Moon occults Venus for people in eastern Australia. From Sydney, Venus disappears behind the bright limb of the 15-percent-lit Moon at 5:31 A.M. Australian Eastern Daylight Time (18h31m UT on the 8th) and reappears after sunrise at 6:54 A.M. AEDT. From locations farther west, the entire event occurs in a dark sky. In Mount Isa, Queensland, Venus disappears at 18h07m UT and reappears at 19h14m UT. The next morning, an even thinner crescent Moon forms a tight triangle with Jupiter and Mars.

**Mercury** also resides in the morning sky, technically at least, but you'll be hard-pressed to see it. At greatest western elongation October 16, it lies 18° from the Sun but stands only 1° high in the east a half-hour before sunrise.

## The starry sky

Look low in the southwest on October evenings and you can't help but notice a pair of bright stars just 4° apart. The yellowish glow of Alpha (α) Centauri contrasts nicely with the blue-white sheen of Beta Cen, the lower of the two. Through a small telescope, Alpha resolves into two stars that orbit each other with an 80-year period. But I want to focus on the faint third member of this system — the red dwarf known as Proxima Centauri. This month marks the centenary of its discovery.

Its story began October 12, 1915, when Robert Innes, the director of the Union

Observatory in Johannesburg, South Africa, issued a circular announcing his discovery of "a faint star of very large proper motion" not far from Alpha Centauri. Proper motion measures the angular movement of an object in the plane of the sky (at right angles to our line of sight). Generally speaking, the larger a star's proper motion, the closer it lies. Imagine yourself in a roomful of flying insects — the ones closest to you would show the largest angular motions. So, a star with a large proper motion draws attention as a candidate for being nearby. This was the first indication that the newly discovered star was close.

Almost immediately thereafter, astronomers set about to measure the star's parallax — the tiny angle subtended by the radius of Earth's orbit at the star's distance. (In practice, researchers determine the apparent displacement of an object as seen from opposite sides of our planet's orbit.) In 1917, Innes published the parallax results for the star, adopting a value of 0.784". That's close to the modern value of 0.769", which implies a distance of 4.24 light-years, making it the Sun's closest neighbor.

Unfortunately, Proxima is not an easy target for small telescopes. Although the 11th-magnitude point of light is bright enough to see in most instruments from a dark site, it is hard to identify in a crowded star field. If you look 2.2° south-southwest of Alpha, however, you'll be looking at the right spot. ☛

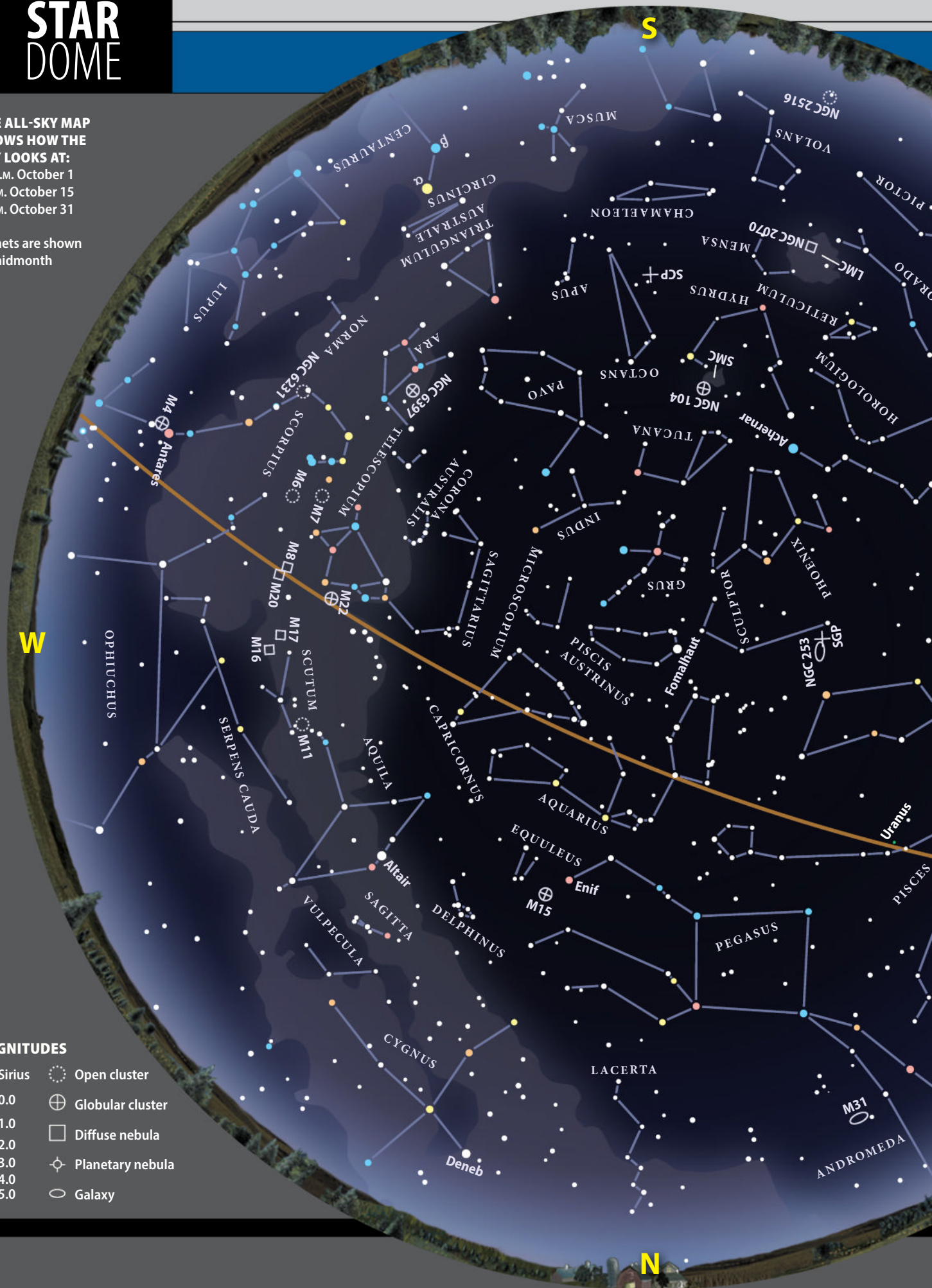
# STAR DOME

**THE ALL-SKY MAP  
SHOWS HOW THE  
SKY LOOKS AT:**  
10 P.M. October 1  
9 P.M. October 15  
8 P.M. October 31

Planets are shown  
at midmonth

## MAGNITUDES

- Sirius
- Open cluster
- 0.0
- ⊕ Globular cluster
- 1.0
- Diffuse nebula
- 2.0
- ⊛ Planetary nebula
- 3.0
- Galaxy
- 4.0
- 5.0





**HOW TO USE THIS MAP:** This map portrays the sky as seen near 30° south latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.



#### STAR COLORS:

Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white without optical aid.

Illustrations by Astronomy: Roen Kelly

## OCTOBER 2015

### Calendar of events

- |  |   |
|--|---|
| <b>2</b> The Moon passes 0.5° north of Aldebaran, 13h UT         | <b>17</b> Mars passes 0.4° north of Jupiter, 14h UT               |
| <b>3</b> Asteroid Eunomia is at opposition, 11h UT               | <b>20</b> First Quarter Moon occurs at 20h31m UT                  |
| <b>4</b> Last Quarter Moon occurs at 21h06m UT                   | <b>21</b> Orionid meteor shower peaks                             |
| <b>8</b> The Moon passes 0.7° south of Venus, 21h UT             | <b>23</b> The Moon passes 3° north of Neptune, 19h UT             |
| Mercury is stationary, 22h UT                                    | <b>25</b> Asteroid Amphitrite is at opposition, 12h UT            |
| <b>9</b> The Moon passes 3° south of Mars, 17h UT                | <b>26</b> Venus is at greatest western elongation (46°), 7h UT    |
| Venus passes 3° south of Regulus, 21h UT                         | Venus passes 1.1° south of Jupiter, 8h UT                         |
| <b>10</b> The Moon passes 3° south of Jupiter, 0h UT             | The Moon passes 0.9° south of Uranus, 10h UT                      |
| <b>11</b> The Moon passes 0.9° south of Mercury, 12h UT          | The Moon is at perigee (358,463 kilometers from Earth), 13h01m UT |
| The Moon is at apogee (406,388 kilometers from Earth), 13h18m UT | <b>27</b> Full Moon occurs at 12h05m UT                           |
| <b>12</b> Uranus is at opposition, 4h UT                         | <b>28</b> Mercury passes 4° north of Spica, 19h UT                |
| <b>13</b> New Moon occurs at 0h06m UT                            | <b>29</b> The Moon passes 0.6° north of Aldebaran, 23h UT         |
| Asteroid Papagena is at opposition, 7h UT                        |   |
| <b>16</b> Mercury is at greatest western elongation (18°), 3h UT |   |
| The Moon passes 3° north of Saturn, 13h UT                       |   |



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